SPATIAL AND TEMPORAL PATTERNS OF AREAL AND VOLUMETRIC PHYTOPLANKTON PRODUCTIVITY OF LAKE TEXOMA

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Phytoplankton productivity of Lake Texoma was measured for one year from August 1999 to August 2000 for four stations, using the oxygen change method and laboratory incubation. Mean values of the photosynthetic parameters, P^Bmax and alpha^B ranged from 4.86 to 46.39 mg O_2.mg $Chl^{-1}.hr^{-1}$ for P^Bmax and 20.06 to 98.96 mg O_2.mg $Chl^{-1}.E^{-1}.m^2$ for alpha^B. These values were in the range to be expected for a highly turbid, temperate reservoir. Estimated gross annual areal productivity ranged from 594 g $C.m^2.yr^{-1}$ (P.Q. = 1.2), at a station in the Washita River Zone to 753 g $C.m^2.yr^{-1}$ at a station in the Red River Zone, of the reservoir. Gross annual areal productivity at Station 17, in the Main Lake Zone, was 708 g $C.m^2.yr^{-1}$. Gross areal and volumetric productivity showed distinct seasonal variation with Photosynthetically Available Radiation (PAR) and temperature. Trophic status estimated on a station-by-station basis, using net productivity values derived from gross productivity and respiration estimates, was mesotrophic for all the stations, though one station approached eutrophy. Net productivity values ranged from 0.74 to 0.91 g C. $m^{-2}.d^{-1}$. An algal bioassay conducted at two stations in August 2000, revealed that phosphorus was most likely the nutrient limiting photosynthesis at both these stations, although the more turbid riverine station was primarily light-limited.

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INTRODUCTION

Ecological Importance of Phytoplankton Productivity

Phytoplanktonic productivity constitutes a major synthesis of organic matter of aquatic ecosystems and often represents the paramount input of new organic matter and potential energy that drives the system. For phytoplankton, autotrophic photosynthesis is the primary mode of nutrition that results in the formation of this new organic matter (Wetzel, 1983). Productivity of plankton forms the base upon which aquatic food chains culminating in the natural fish populations exploited by man are founded. At the same time it generates about 70% of the world's atmospheric oxygen supply (Reynolds, 1984).

Excessive algal production in lakes and reservoirs, however, can interfere significantly with their uses and aesthetic quality (Ryding and Rast, 1989). Increased nutrient loadings to these water bodies as a result of human activities in their watersheds can lead to a dramatic increase in biomass productivity. This resulting process of accelerated change is termed cultural eutrophication (Henderson-Sellers and Markland, 1987). Lakes and reservoirs undergoing cultural eutrophication may show symptoms such as increased algal biomass, increased pH, depletion of dissolved oxygen, fish kills (Harper, 1992), reduced water clarity, and unpleasant tastes and odors (Henderson-Sellers and Markland, 1987). These changes to water quality affect uses such as drinking water supply, industrial uses, irrigation and recreation (Ryding and Rast, 1989).

Reservoir Zonation

Reservoirs exhibit a large degree of spatial heterogeneity in phytoplankton productivity and biomass as a result of longitudinal gradients in basin morphology, water residence time, flow velocity, suspended solids, and the availability of light and nutrients (Kimmel et al., 1990). A typical reservoir commonly has three distinguishable zones along its longitudinal axis (Figure 1):

1. The uplake riverine zone which is characterized by higher flow, shorter water residence time, and higher levels of available nutrients, suspended solids, and light extinction relative to downstream portions. Abiogenic turbidity will often limit light penetration, thereby limiting the thickness of the photic layer. Areal primary productivity is often light limited.
2. The transition zone, characterized by higher phytoplankton productivity and biomass. This occurs in conjunction with increasing breadth of the basin, decreasing flow velocity, increased water residence time, sedimentation of silt and clay particles from near-surface waters, and increased light penetration. The transition zone can be the most fertile region of a reservoir because both light and nutrients are available for algal photosynthesis.
3. The lacustrine zone which occurs nearest the dam and usually has the longest water residence time. It also exhibits lower concentrations of dissolved nutrients and suspended abiogenic particles, higher water

transparency, and a deeper photic layer. However, the volumetric phytoplankton productivity of the photic zone is reduced, often by nutrient limitation, during most of the growing season, and is supported mostly by *in situ* nutrient cycling rather than by advected nutrients (Kimmel et al., 1990).

Reservoir Productivity: Some Unique Aspects

Reservoirs occupy an intermediate position between rivers and natural lakes with respect to their morphologic and hydrologic characteristics and their sources of organic matter (Kimmel et al., 1990; Ryder et al., 1974). Phytoplankton productivity and biomass levels in reservoirs are dependent on interrelated physical, chemical, and biological factors that are functions of the climatic and hydrologic patterns, the size and nature of the watershed, reservoir basin morphology, nature and volume of river inflow, and reservoir food-web structure. Two primary factors that control phytoplankton productivity in reservoirs are light and nutrient availability. These are functions of inflow characteristics, such as suspended sediment and dissolved nutrient loads, and the vertical mixing pattern (Kimmel et al., 1990). Vertical patterns, driven by thermal differences between the surface and deeper layers of the water column, appear in both lakes and reservoirs, as do lateral gradients as a consequence of changes in depth. Reservoirs, however, also have a distinct longitudinal (upstream to downstream) gradient because they occur where flowing waters have been impounded (Thornton, 1982).

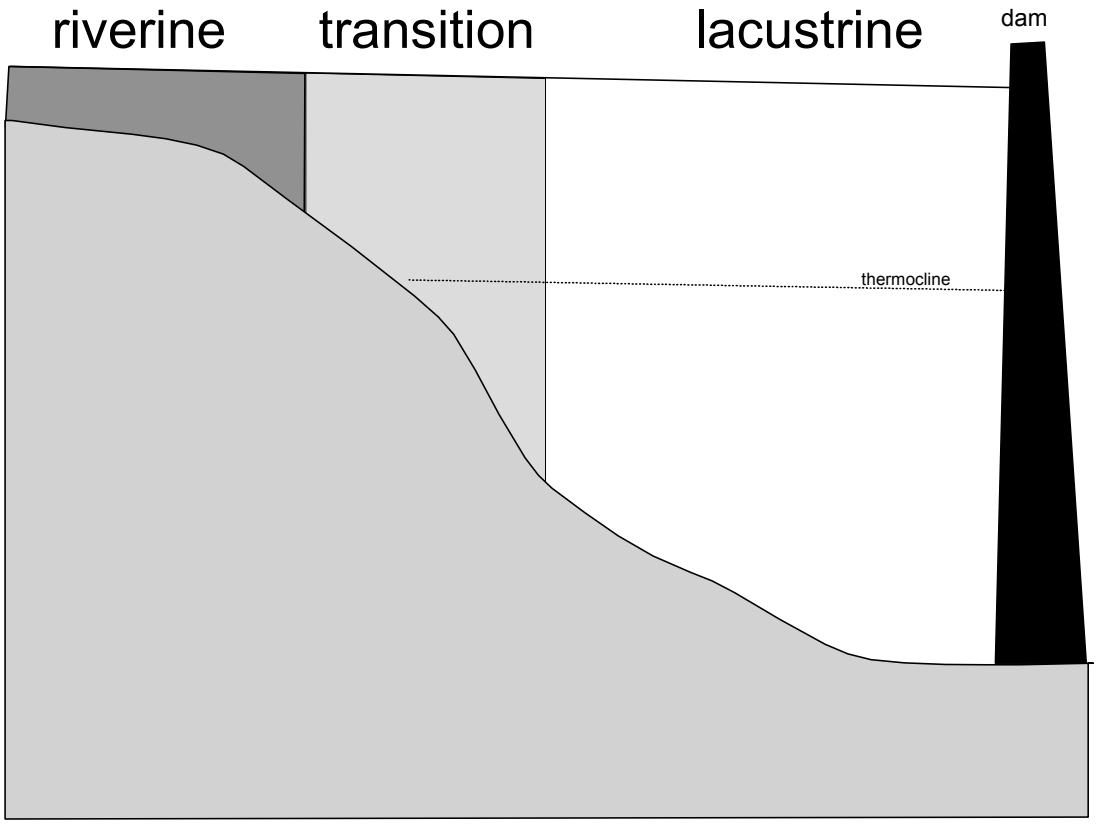

Figure 1. Horizontal zonation of a typical reservoir, showing the riverine, lacustrine, and transition zones.

As a group, reservoirs are thought to be somewhat more productive than natural lakes (Kimmel et al., 1990; Kimmel and Groeger, 1984). In addition, most reservoirs have significantly higher drainage-area-to-lake-surface-area ratios. They also have greater external nutrient loading, and shorter water residence times than most natural lakes (Kimmel et al., 1990).

Kimmel et al (1990) suggested, based on mean daily productivity values for the whole year for a number of temperate and tropical reservoirs, that, if daily productivity data were available, productivity in most reservoirs would likely be more variable than in most natural lakes. This would be a result of more rapid flushing rates and the continued influence of inflow from the impounded river.

Nutrient Limitation

The limiting nutrient concept was first advanced by Liebig in the 1840s. His "Law of the Minimum" simply states that the yield of an organism will be limited by the essential factor in its environment that is present in the least amount, relative to the need of the organism. Liebig's law has been applied to phytoplankton growth in lakes and reservoirs and it has been found that more than one nutrient can limit growth at the same time (e.g. Miller et al., 1978; Sridharan and Lee, 1977; Morris and Lewis, 1988)

Nutrient enrichment bioassays have been widely used to study nutrient limitation in aquatic environments. A nutrient enrichment bioassay is a test for nutrient limitation in which one or more nutrients is supplied to a test algal species growing in filtered water

or to the natural phytoplankton to determine if there is an increase in production or biomass or changes in cellular characteristics (Gerhart and Likens, 1975).

Gerhart and Likens (1975) compared four methods for conducting enrichment experiments to determine nutrient limitation in Mirror Lake, New Hampshire. The methods compared were enrichments of large *in situ* polyethylene enclosures , enrichment of continuous cultures of natural phytoplankton, short-term *in situ* ^{14}C bioassays, and long term ^{14}C bioassays on subsamples of water from enriched cultures. They found that their enrichments of large polyethylene enclosures, continuous cultures of the natural phytoplankton community, and long-term ^{14}C bioassays agreed in showing that nitrogen and phosphorus limited phytoplankton growth in Mirror Lake. Their short-term (4-30 hr) bioassays, however, showed that nitrogen and phosphorus enrichments did not stimulate phytoplankton production and they concluded that care should be taken in extrapolating the results from short term bottle bioassays to measures for controlling eutrophication.

Hecky and Kilham (1988) reviewed evidence on the effects of nutrient enrichment while examining nutrient limitation of phytoplankton in freshwater and marine environments. For convenience, they divided nutrient enrichment assays into four levels of increasing complexity of test system organization: level I consisting of an assay of cultured algae lasting for hours to days, level II a community culture using the natural algal community and lasting for days; level III an assay involving an enclosure or mesocosm employing the natural algal community and lasting for days to months, and level IV an assay involving rivers, lakes, bays, or oceans, that would use the natural algal community of those systems and last for months to years. They suggested that, the higher

the level of the experimental test, the more applicable the results would be to the natural situation of interest and were of the opinion that level I tests could only suggest potential nutrient limitation (Hecky and Kilham, 1988).

Lake Texoma Characteristics

Lake Texoma is a 36,000 ha (89,000 acre) impoundment which occupies portions of both south central Oklahoma and north central Texas (Atkinson et al., 1999). Completed in 1944, by the U.S. Army Corps of Engineers, the reservoir drains an area of approximately 103,000 km^2 (39, 719 $miles^2$). Most of this area is pasture and cropland. The major rivers that flow into Lake Texoma are the Red River and the Washita River (Atkinson et al., 1999). Lake Texoma provides a number of uses such as flood control, hydropower, water supply, navigation, streamflow regulation, and recreation (Atkinson, et al., 1999). The reservoir has a variety of game and non-game fish species and is well known for its striped bass, bass, and catfish (Oklahoma Reservoir Fact Sheet, 1995). Based on historical water quality data, Atkinson et al (1999) divided the lake into five zones 1.) The Red River Zone, 2.) The Red River Transition Zone, 3.) The Main Lake Zone, 4.) The Washita River Transition Zone, and 5.) The Washita River Zone. This classification corresponds closely to the reservoir zonation of uplake riverine, transition, and lacustrine, delineated by Kimmel et al., (1990). The Main Lake Zone classified by Atkinson et al., (1999) corresponds to the lacustrine zone, the Red River and Washita River zones to the uplake riverine zone, and the Red River and Washita River Transition Zones, to the transition zone of Kimmel et al.

Previous Investigations of Lake Texoma

Lake Texoma has been the focus of various studies in the past. Three of the studies (Sublette, 1955; Hubbs et al., 1976; Matthews and Hill, 1988) explored physico-chemical and biological features of Lake Texoma. Sublette (1955) observed, from the results of oxygen determinations on samples, that there was no instance of complete depletion of oxygen in the hypolimnion of the lake. Hubbs et al (1976), in studying the effects of a halocline on fish distribution in the Red River Arm of Lake Texoma, found that the primary cause of stratification on this arm of the lake was differing concentrations of dissolved solids. This caused the development of a halocline. The halocline resulted in an anoxic hypolimnion, and subsequently, a thermocline formed at the same depth as the halocline.

Matthews and Hill (1988) made weekly determinations of vertical physico-chemical profiles as well as fish distribution in the summers of 1982 and 1983, at five stations in the main basin of the reservoir. While studying vertical profiles, they found that there were differences between years in the depth of the chemocline, although the basic pattern of stratification of the lake was similar from July to early September in both years.

Baglin (1972) also investigated some physico-chemical conditions as well as surface phytoplankton. He discovered that the greatest number of algal genera and individuals present were to be found in the areas of highest salinity and conductivity of the lake.

Two other studies (McCullough, 1978; Ellis, 1980) dealt with aspects of phytoplankton distribution and size. McCullough (1978) analyzed phytoplankton communities of the lake and investigated the correlation of physicochemical data with phytoplankton distribution and abundance. In agreement with the findings of Hubb et al (1976), he observed that minerals leached from sediments in the Red River channel contributed to the establishment of a halocline, with only intermittent thermocline formation. In addition, anoxic conditions developing in a large portion of the total reservoir volume, and the presence of algae common to many lakes classified as eutrophic, led him to conclude that Lake Texoma exhibited a trend towards eutrophication.

McCullough also observed a general increase in phytoplankton standing crop (represented as the calculated geometric volume of phytoplankton cells), commencing in spring and continuing through midsummer. A minimum standing crop was evident through late summer and fall, increasing in winter.

Ellis (1980), as part of her study, determined, by the use of autoradiography, the relative contributions of various organisms and phyla to the metabolism of plankton communities in the lake. Her study site was located near the deeper, pelagic area of the reservoir and was selected partly because it was representative of the midlake area of the reservoir.

She estimated primary productivity using the ^{14}C-tracer technique, modified for filtration and non-filtration processing. Her estimates of primary productivity determined by these two techniques showed good agreement. Ellis found that primary productivity

values were higher during October 1978, though greater plankton densities occurred during the summer. She found that her estimates of net primary productivity and phytoplankton densities for Lake Texoma were within the range reported by Wetzel (1983) for a eutrophic water body. Her mean net primary productivity was 2628 mg $C.m^{-2}.d^{-1}$ and 876.0 mg $C.m^{-3}.d^{-1}$, based on one summer and one fall sampling in 1978. This observation regarding trophic state was in agreement with that of McCullough (1978).

More recent studies (Gade, 1992; Ground and Groeger, 1994; Gibbs, 1998; Rolbiecki, 1998; Atkinson, et al., 1999) have focused on predicting the effects of chloride reduction, and on trophic status, chlorophyll-a (chl-a) concentrations, the underwater optical properties of Lake Texoma, and water quality, respectively. Gade (1992) evaluated the possible effects of chloride reduction in Lake Texoma on the striped bass fishery. The primary objective of the study was to determine if a reduction of dissolved chloride might trigger an increase in clay turbidity, leading to a decrease in algal biomass (as represented by chl-a concentration). The decrease in biomass would result from a decrease in euphotic depth, which would ultimately lead to a decrease in sport fish production and a decline in the fish harvest.

Dissolved chloride acts as a flocculating electrolyte, causing clay particles to aggregate and form masses of greater size and density. These masses are more likely to settle out of solution, reducing turbidity. Decreases in dissolved chloride would allow clay particles to remain in suspension for a longer time, thereby increasing turbidity (Gade, 1992).

Gade found that chloride control would decrease Secchi depths in the segments of the lake that would be subject to the chloride control measures and that would have their turbidity impacted by chloride control because of their location. Increasingly effective chloride control in these same segments of the lake decreased chl-a levels there, as well as for the lake as a whole. These predicted decreases were, however, relatively small when variability associated with chl-a concentrations was taken into account (Gade, 1992).

Mean chl-a levels in other segments remained stable at all levels of chloride control and this mitigated the predicted decrease in chl-a levels for the lake as a whole.

Base angler sportfish harvest predicted at chl-a levels associated with no chloride control, decreased with increasingly effective chloride control. Some parts of the lake showed less sensitivity than others (Gade, 1992).

Ground and Groeger (1994) chemically classified and characterized the trophic status of 80 Texas reservoirs including Lake Texoma. Table 1 shows characteristics of a few of the reservoirs studied. The trophic status of Lake Texoma was shown, based on mean growing season, near-dam chl-a concentrations, surface area, mean depth, drainage basin area, specific conductance, total phosphorous, and Secchi disc transparency, to be mesotrophic (4-10 $mg.m^{-3}$ chl-a).

Gibbs (1998) examined environmental factors influencing chl-a concentrations in the lake. Based on knowledge about how zone characteristics can affect algal productivity, she investigated the relationships between the zone types. According to her findings, the general trend for all the zones was that periods of high chl-a biomass existed

Table 1. Characteristics of selected Texas reservoirs (adapted from Ground and Groeger, 1994).

Reservoir	S.A. (km^2)	M.D. (m)	DBA (km^2)	Sp. Cond. (uS/cm)	Chl-a (ug/L)	TP (ug/L)	Secchi (m)	Years	n
Granbury	34.4	5.5	41,731	2,346	12.4	30	1.1	5	5
Possum Kingdom	80.1	11.2	36,336	2,808	4.4	47	2.2	5	5
Texoma	360.2	9.3	87,498	1,827	6.5	54	1.9	4	5
Eagle Mountain	37.2	6.3	5,102	436	8.5	38	1.3	5	13
Grapevine	29.9	7.8	1,800	353	12.0	30	1.4	5	5
Lewisville	94.2	6.1	4,299	353	8.6	93	1.2	6	7
Ray Hubbard	92.0	6.6	2,774	287	16.2	75	0.9	6	10
Waco	29.4	6.4	4,279	344	5.6	22	0.9	5	6
Lake Fork	112.1	7.4	1,269	195	8.9	34	1.7	4	5
Lake O' the Pines	75.6	4.2	2,202	153	11.9	20	2.3	5	6
Sam Rayburn	458.9	7.8	8,933	205	3.9	60	1.8	3	3
Toledo Bend	734.9	7.5	18,591	185	4.8	34	2.4	6	10

S.A. - Surface Area

M.D. - Mean Depth

DBA - Drainage Basin Area

Sp. Cond. - Specific Conductance

T.P. - Total Phosphorus

n - Total Number of Samples

in June through August, tapering off in September. Gibbs found that the Main Lake body tended to have the least concentration of algal biomass and the chl-a concentrations in this zone exhibited the least amount of variability in agreement with the findings of Atkinson et al., (1999). The Red River Zone exhibited occasional peaks of chl-a concentrations. The Red River Transition Zone also showed a periodic cycle of chl-a concentration, though of less magnitude than the Red River Zone. The Washita River and its Transition Zone closely followed the trends of the Main Lake body. Gibbs measured twenty-three physical and chemical parameters in addition to chl-a concentrations. Of these, she limited her investigation to variables representative of light availability and nutrient concentrations. These were mainly total phosphorous, total suspended solids, Secchi depth, and chlorides. Using algorithms prescribed by Carlson (1977) for determining trophic status, Gibbs determined the trophic state indices (TSIs) for Secchi depth, chl-a, and total phosphorus for each zone, for each sampling event. Trophic status is the assignment of a qualitative description of one of a discrete set of categories (basically oligotrophic, mesotrophic, or eutrophic) to a water body, based on nutrient concentrations (Henderson-Sellers and Markland, 1987). Although the trophic status is a statement about nutrient concentrations within a water body, such parameters may be difficult to monitor. Therefore, other parameters such as chl-a, Secchi disc depth, and dissolved oxygen, which are easier to measure than nutrient concentrations, are often used as a surrogate for indicating nutrient levels. The correlation between these individual indicators, however, is not perfect and a water body may appear to be eutrophic when using one indicator, but mesotrophic—or even oligotrophic—when using another

(Henderson-Sellers and Markland, 1987). Consequently, there has been a search for a method of combining two or more of these parameters into a single TSI. The TSI can be regarded as a simple model in which one or more characteristics of a waterbody are assigned a numerical value (Henderson-Sellers and Markland, 1987). Carlson (1977) developed a TSI, which is now commonly used in limnological studies.

Gibbs found that for Lake Texoma, the TSI calculated from total phosphorus consistently characterized the reservoir as oligotrophic. TSIs calculated from Secchi depth and chl-a values, showed that the reservoir is primarily eutrophic, and seasonally mesotrophic. Based on the shortage of total phosphorous in the system, she suggested that Lake Texoma was likely phosphorus limited.

Rolbiecki (1998) characterized the underwater optical properties of the lake using Secchi depth, submarine photometry, and high-resolution spectroscopy. He found a distinct longitudinal gradient in Secchi depth, extinction coefficients, and depth of the euphotic zone (Z_{eu}) from the Red and Washita River Zones to the Main Lake Zone. Attenuation was highest in the river zones and lowest in the Main Lake Zone, while Secchi depth and Z_{eu} were lowest in the river zones and highest in the Main Lake Zone. There were differences, both spatially and temporally among extinction coefficients, Secchi depth, and Z_{eu}. Chl-a was not significantly related to extinction coefficient or Secchi depth. Rolbiecki's results were in general agreement with those of Atkinson et al. (1999).

Atkinson, et al. (1999) determined spatial and temporal aspects of water quality in the lake based on historical data analyzed from studies they reviewed. Results of their

study showed that the highest values and greatest variability of chl-a was to be found in the Red River and Washita River Zones. The Main Lake body had the lowest values and least variability of chl-a. Months of lower turbidity such as July, August, and September, generally showed higher chl-a concentrations. Water clarity was highest in the Main Lake body and diminished towards both river arms where turbidity was greatest. All zones showed some vertical stratification from May until late September, although Stations 9 and 22 showed a chemocline rather than the traditional thermocline (Atkinson et al., 1999).

There is a need to study the productivity of phytoplankton in Lake Texoma because it has the potential to affect recreational fishing. Gade's study used chl-a as a measure of lake production to study the effect of decreased chloride concentrations on sportfish abundance. The current study will provide direct estimates of primary productivity that can be used as baseline data for other productivity studies exploring impacts of reduced chloride concentrations on the sports fishery. Additionally, primary productivity of phytoplankton is arguably among the best criterion for determining the trophic status of a lake. Goldman (1988) states that the measurement of primary productivity supplies a photosynthetic integration of physical, chemical, and biological conditions, and when conducted over time, it is an excellent measure of change in the trophic state of an aquatic system. Wetzel (1983), however, maintains that this is only a valid criterion for such a determination if organic matter inputs from the littoral and allochthonous sources are small in relation to those of the phytoplankton. According to Kennedy and Walker (1990), Lake Texoma receives high sediment inputs. Deposits

occur in shallow upstream as well as deep areas of the lake and reflect a combination of the influences of allochthonous organic matter inputs from the Red and Washita Rivers and autochthonous production. Hence the volume of allochthonous input to Lake Texoma may interfere with an accurate determination of trophic status.

Although in Goldman's study, primary productivity was measured with ^{14}C, Williams et al. (1979) found that the agreement between the ^{14}C and oxygen methods of measuring phytoplankton photosynthesis was potentially quite good, although both methods had limitations. Therefore, any determinations of trophic status, as made by the current study, will have some utility.

Trophic status characterizations help to determine the susceptibility of the water quality in the waterbody to changes in land use, population, and climate (Ground and Groeger, 1994). This primary productivity study can provide another estimate of the trophic status of the reservoir on a station-by-station basis. This would help to facilitate comparisons with the findings of Ground and Groeger and Gibbs, through the use of different methodology, and determine if there have been major changes in trophic status.

Finally, Bowman (1994) writes that estimates predict the population of Texas more than doubling over the next fifty years, with a projected increase in the demand for water within the state. Thus, studies generating data that carry implications for management of water resources, such as Lake Texoma, continue to be useful.

Focus of Current Research

The objectives of this study were to:

1) determine the temporal variability of areal and volumetric phytoplankton productivity at four stations representative of the different zones of the reservoir
2) determine the spatial variability in areal and volumetric phytoplankton productivity at these four stations
3) determine which nutrient parameters most likely limited phytoplankton biomass at a riverine and a main lake station
4) determine the current trophic status of each station

This study tested three hypotheses:

1) Ho: Annual areal and volumetric phytoplankton productivity is the same at all stations on the lake
2) Ho: Daily areal and volumetric phytoplankton productivity does not vary seasonally
3) Ho: Nutrient availability does not impact algal biomass

MATERIALS AND METHODS

Field Data Collection

Temperature, Secchi depth, light extinction and chl-a field data were collected by personnel sampling for the ongoing Water Quality Monitoring Program (WQMP) conducted by the University of North Texas, on which Atkinson et al. (1999) reported. The WQMP is a study funded by the U.S. Army Corps of Engineers and is designed to establish base line physical, chemical, and biological data for Lake Texoma over time, so that any changes in water quality of the lake from a planned, phased chloride-reduction program can be evaluated.

Temperature and turbidity data were collected as part of overall depth profile data. Depth profiles were determined with a Hydrolab (H20) datasonde lowered in two-meter intervals beginning one meter below the surface and ending one meter above the bottom. In the current study, only temperatures at the depth of one meter were used. Turbidity was determined in the laboratory from a water sample collected at one meter.

Secchi depth in meters was determined by lowering a Secchi disk into the water from the shaded side of the boat, and averaging depths when it disappeared and when it reappeared after being raised. Three sets of readings were taken at each station and an overall average calculated (Atkinson et al., 1999).

A Protomatic submarine photometer was used to gather light extinction data beginning at the surface and at 1m intervals down to the approximate depth of the

euphotic zone (1% of incident light). The extinction coefficient (η") at depth (z) below the surface was calculated in the following way:

$$\eta'' = \frac{\ln I_o - \ln I_z}{z}$$

where:

I_o = irradiance at the surface
I_z = irradiance at depth z (m) (Wetzel 1983).

The total vertical extinction coefficient over the entire light-depth profile (η") was then calculated by the least square estimate (Lind,1979a). This total extinction coefficient is a composite of the components of water, suspended particles, and dissolved, colored components in the water column (Wetzel, 1983).

Chl-a was determined using water samples pumped from 1m below the surface. Ten replicates, each of 1L, were used for chl-a determination according to specified methods (American Public Health Association [APHA], 1992). Samples were filtered through non-precombusted GF/F filters within twenty-four hours of collection, using a vacuum pump. Filters were then ground with aqueous acetone solution consisting of 90 parts acetone and 10 parts saturated magnesium carbonate solution and stored in the dark at 4^oC for 24 ± 6 hours, to extract the chlorophyll. The extract was clarified by filtration and transferred to a 1cm cuvette. Its optical density was determined at 750 and 664 nm in a Beckman DU-64 spectrophotometer. The extract was acidified with 0.1 N Hydrochloric acid to convert chl-a to pheophytin-a. This was done to avoid overestimation of chl-a through including pheopigments that would absorb near the same wavelength as chl-a (APHA, 1992). About ninety seconds after acidification, the optical density at 750 and at

665 nm was read and optical density values were used to calculate chl-a and pheophytin-a per cubic meter.

Phytoplankton Photosynthesis vs. Irradiance Assays

Fee (1973) contended that the popular *in situ* method for measuring phytoplankton production was not adequate for measuring the production of large water bodies because the number of stations that could be processed each day was too small to provide a comprehensive view of the waterbody. He added that since natural light was being used, the experiments could only be performed during a brief part of the day. This would be wasteful in the event that ship time was costly, or large areas were being studied. In addition, the *in situ* method suffers from high variability induced by day-to-day changes in cloud cover. He proposed a laboratory method for determining phytoplankton production vs. irradiance assays conducted in the laboratory under controlled light and temperature conditions. This laboratory-based approach was adopted for this study.

Water samples from four stations (Stations 3, 9, 17, and 22, Figure 2) were collected each month (bimonthly in the months of May and June), in coolers and transported to the laboratory for sample incubation procedures. Sampling locations were chosen based on the zones delineated by Atkinson et al (1999). Sampling locations representative of four of the five zones were chosen. Samples were collected from 1 m depth utilizing a Teel water pump and ¾ inch OD, ½ inch ID hose.

When each cooler arrived in the laboratory, a mixture of gases containing CO_2 in atmospheric concentrations (~350 ppm CO_2), six percent O_2 and the balance of N_2 was

bubbled through it to lower the oxygen level of the sample. High oxygen concentrations cause photorespiration in the algae and this would lead to true net photosynthesis being underestimated. The oxygen level of the samples was adjusted so that there was little danger of photorespiration occurring in the algae and affecting the measurement of the rate of photosynthesis. Sample incubations were typically initiated within 6 hours of sample collection in the field.

Phytosynthesis was determined as the change in oxygen concentration of subsamples incubated in Biochemical Oxygen Demand (BOD) bottles under various light levels. Incubation was conducted under five different light intensities ranging from 0 (dark) to about 360 $\mu E.m^{-2}.s^{-1}$. Four subsamples were incubated at each of the 5 light levels in a water bath maintained within $1^{o}C$ of lake temperature. Prior to incubation, initial oxygen concentration was measured in all of the bottles using a YSI oxygen meter (Model 5000) and a YSI self-stirring BOD probe (Model 5010). Four bottles were then placed under each source of different light intensity within the water bath. The dark bottles were placed at random in the water bath since they would not be affected by any of the light sources. Incubations lasted 12-18 hours, after which final oxygen concentration in each BOD bottle was measured.

The oxygen change in each bottle was calculated as the difference between the initial and final concentrations and was normalized to plankton biomass using the chl-a measurements.

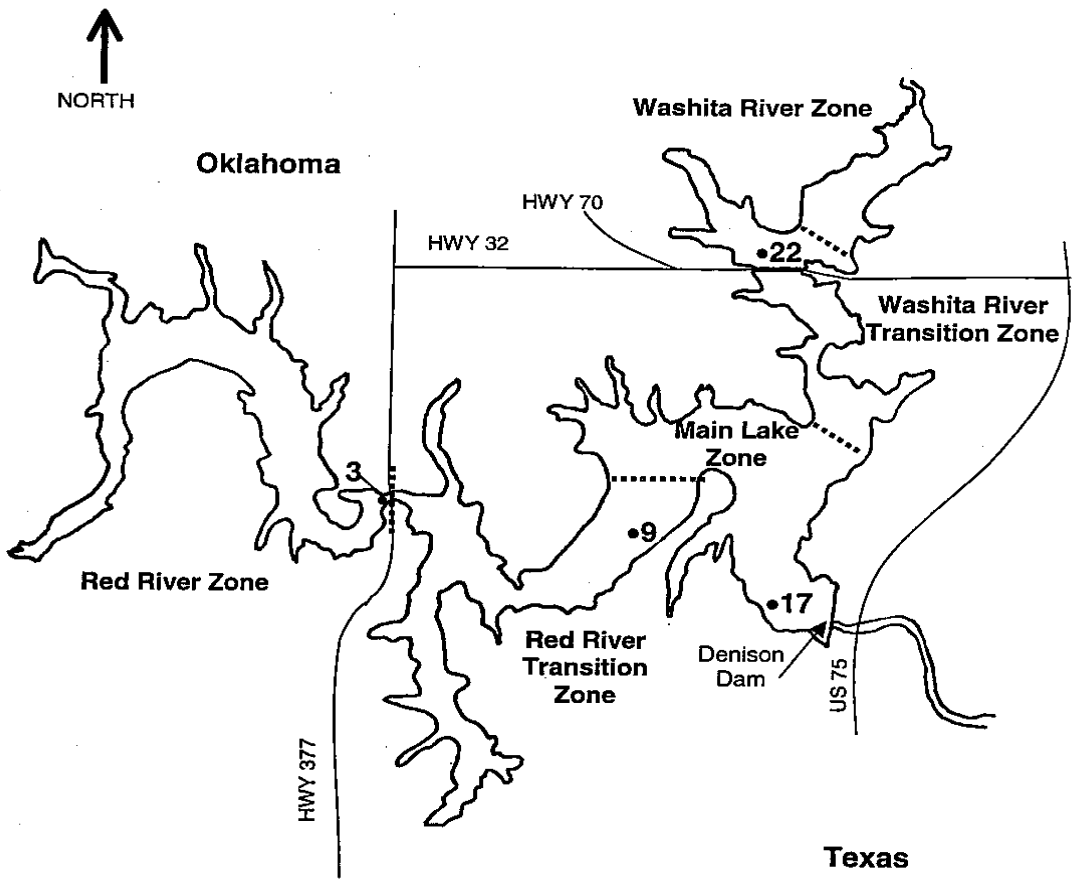

Figure 2. Location of sampling sites on Lake Texoma.

The data from these experiments were then fit to the hyperbolic tangent model of Jassby and Platt (1976) to yield the photosynthetic parameters P^B_{max} and $alpha^B$:

$$Pb = P^B_{max} * \tanh [(I * alpha) / P^B_{max}]$$

where:

Pb = gross photosynthesis per unit chl-a
P^Bmax = light saturated rate of photosynthesis per unit chl-a
tanh = hyperbolic tangent
alpha = initial slope of the P^B-I curve at low light
I = light energy

Control bottles filled with deionized water were routinely assayed along with the phytoplankton samples to ensure proper operation of the oxygen probe. Oxygen concentrations typically changed between 0.30 and 2.50 mg/l in bottles for dark and highest light levels, respectively.

Calculation of Daily Areal Productivity

Calculations of daily areal productivity were performed using the method of Fee (1998). The computer program that makes these calculations is available at http:// www.unmanitoba.ca/institutes/fisheries/Pspgms.html. According to Fee, three relationships must be known in order to calculate daily areal productivity. These are: 1.) incident surface light as a function of time (I_o[t]; top curve in Figure 3., 2.) photosynthesis as a function of irradiance (P vs. I; middle curve), and 3.) percent of solar PAR as a function of depth ([I_z]; bottom left curve), expressed as a percentage.

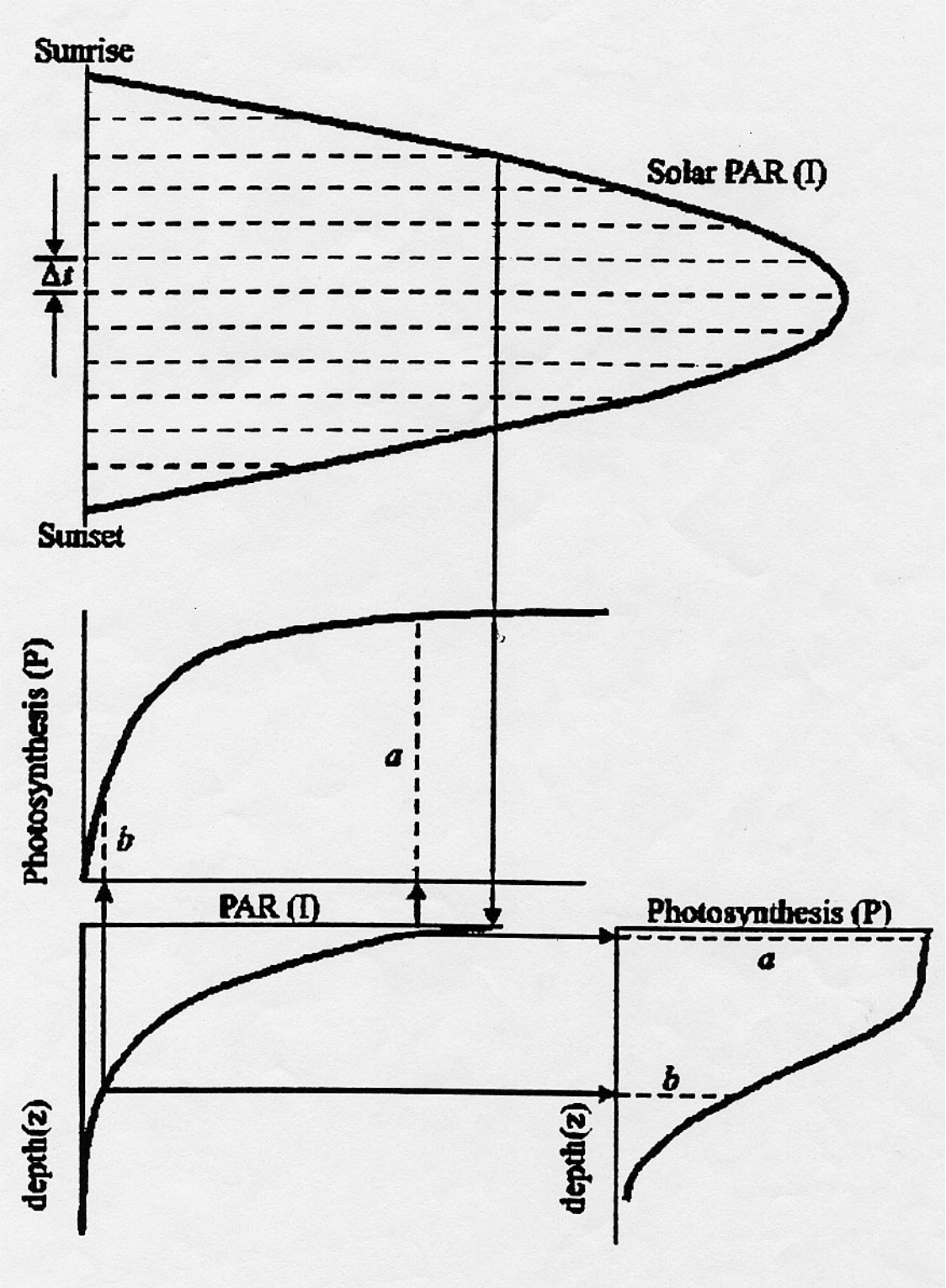

Figure 3. The procedure used to estimate *in situ* photosynthesis (Fee, 1990).

Incident surface light data were obtained from the Oklahoma State University Mesonet. As these data were not available for Lake Texoma, data from Durant, Oklahoma, a station ten miles from the lake, were used instead. The data were in units of $W.m^{-2}$ and were collected at the Mesonet station at 30-minute intervals using a Licor model 200 silicon photodiode pyranometer. Data for the period August 1999 to August 2000 were used. They were obtained in the form of separate light files for each individual day during the specified period.

Each light file was imported into Excel. Times were in Co-ordinated Universal Time (UTC) format so they were converted to either Central Standard Time or Central Daylight Time as required. Each separate file containing daily incident surface light data was then consolidated with other files for the same month, creating files containing monthly data. Incident surface light data in $W.m^{-2}$ was then converted into PAR assuming a conversion factor of 1 $W.m^{-2}$ = 4.6 $\mu E.m^{-2}.s^{-1}$ (Biggs, 1986) and that approximately 50% of total solar radiation was in the 400-700 nm range of PAR (Kirk, 1994). PAR in $\mu E.m^{-2}.s^{-1}$ was in turn converted to $mE.m^{-2}.min^{-1}$ because these were the units required by Fee's program. Photosynthesis vs. irradiance curves were determinable from laboratory results of the photosynthesis vs. irradiance assays as described above. Gross productivity was calculated for each data set by adding back the observed dark respiration value for each light level.

The depth profile of PAR (Figure 3, bottom left curve) is calculated by multiplying I_o by the percent of surface light that reaches each depth I_z, for a given instantaneous value of I_o. Photosynthesis as a function of depth (P_z; Figure 3, bottom

right curve) is then calculated from the relationship between photosynthesis and light intensity determined by the P vs. I curve. The instantaneous areal rate of photosynthesis is calculated by integration of the P_z curve from the surface down to the depth of the euphotic zone (Z_{eu}). The whole procedure is repeated at successive time intervals (Δt) (Figure 3, top curve) in order to obtain a set of instantaneous depth integrals over the entire day (Fee, 1998). The P vs. I curve which is key to this calculation is illustrated in Figure 4.

A simplification of the hyperbolic function of Jassby and Platt (1976) was utilized by Fee (1998) to determine areal productivities as follows:

$P = 0$ if I is less than $I_k / 20$

$P = B*P^Bmax$ if I is greater than or equal to $2*I_k$

$P = B*alpha^B*I'(1-I')/(4*I_k)$ otherwise,

where P is the rate of gross photosynthesis, I is PAR, $I_k = P^Bmax/alpha^B$, and $I' = I-(I_k / 20)$.
(B is chlorophyll concentration and $alpha^B$ is the slope of the P vs. I curve as PAR approaches zero divided by chlorophyll concentration).

Areal gross productivity was calculated using daily PAR data. The input variables, (light extinction, chl-a, P^Bmax, and $alpha^B$), however, were entered in monthly intervals. Fee's program linearly interpolated these variables for days between sampling dates, though it did not produce the interpolation output. Light extinction, chl-a, and respiration rate were therefore interpolated using the "Fill" function in Excel. Daily extinction data generated in Excel were used to calculate daily Z_{eu} as follows:

$$\eta''z = \ln I_o - \ln I_z$$

$$z = \frac{\ln I_o - \ln I_z}{\eta''}$$

$$Z_{eu} = \frac{4.605}{\eta''}$$

where:

I_o = irradiance at the surface as a percentage (100%)
I_z = irradiance at depth z (m) of euphotic zone as a percentage (1%)

Euphotic zone depth was then used, together with daily respiration and chl-a data, to compute the daily areal respiration rate. The latter, when subtracted from daily areal gross productivity, yielded daily net productivity.

Nutrient Enrichment Algal Bioassay

A level I algal bioassay (Hecky and Kilham, 1988) was conducted on one date during the period of research using subsamples from Stations 17 and 22. The experimental procedure delineated by the EPA in the bottle test (Miller et al., 1978) was followed as closely as possible. On the date of the bioassay, the coolers bearing the water samples from each station were filled to the brim to ensure that there would be enough lake water left for the bioassays after the irradiance assays. In the laboratory, the lake water remaining from Station 17 and 22 coolers, after subsamples were removed for irradiance assays and chl-a determination, was filtered with AE glass fiber filters and then with 0.45 μm pore size membrane filters to remove particulate matter including most living algal cells. The filtered water was stored overnight in clean coolers as the

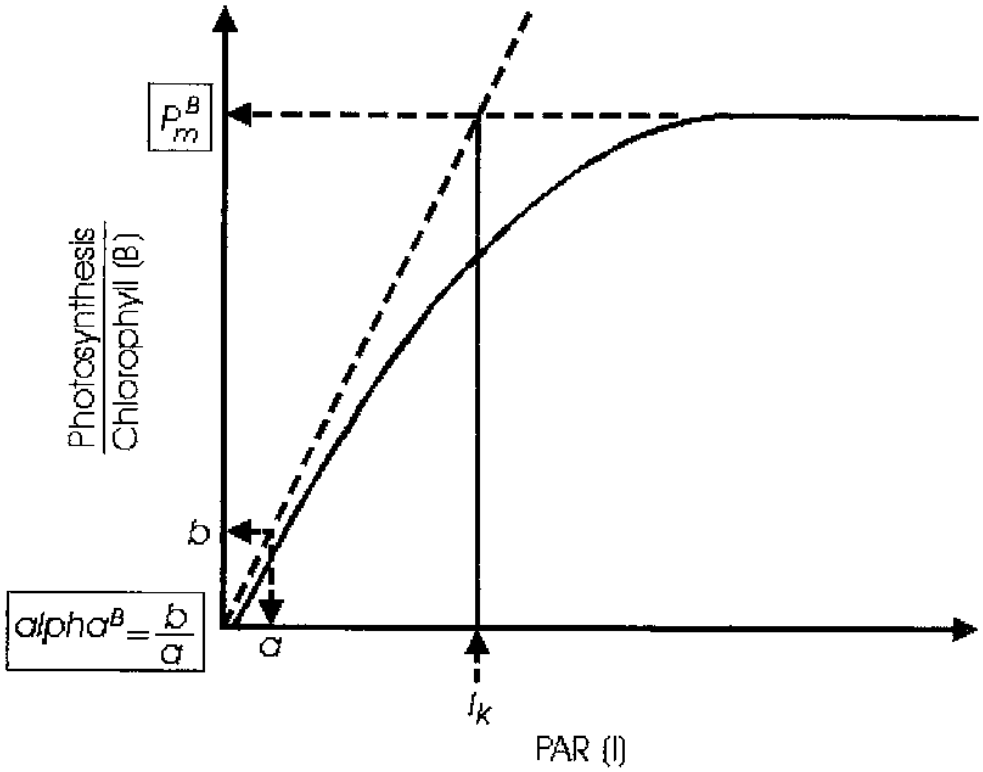

Figure 4. The photosynthesis vs. PAR curve, illustrating the equation used and graphically defining the photosynthetic parameters (modified from Fee [1998]).

bioassays could not be conducted on the same day the samples were drawn from the lake owing to logistical constraints in the laboratory.

Selenastrum capricornutum inoculum was obtained from a research laboratory at the University of North Texas where *Selenastrum* is routinely cultured and used for toxicity testing. The inoculum was grown in Algal Assay Procedure medium. The *Selenastrum* was centrifuged twice at 500 x g for ten minutes and resuspended in deionized water to separate the cells from the nutrient-rich growth medium.

The bioassays were conducted with five replicates per treatment, using 50 ml water samples in 250 ml Erlenmeyer flasks. Each culture flask was inoculated with 1 ml of the resuspended *Selenastrum* culture.

Three nutrient treatments and a control were used. Nutrient treatments consisted of spiking flasks bearing each set of replicates with either nitrogen in the form of sodium nitrate, phosphorous in the form of potassium phosphate, or nitrogen and phosphorous in the forms mentioned above (Table 2). The control consisted of flasks to which no nutrient treatment was applied. The flasks were plugged with cotton balls and incubated at $24^{o} \pm 2^{o}$ C with a light intensity approximately equal to 76 $\mu E.m^{-2}.s^{-1}$ (Linton and Goulder, 1998). The bottles were gently agitated twice daily and phytoplankton fluorescence was measured, with temperature correction, through time (8 days) until a clear maximum level of fluorescence was obtained.

Table 2. Treatments used for algal bioassay experimental groups.

TREATMENT	FORM	CONCENTRATION (g/L)
Control-no nutrient additions		
Phosphorus	K_2HPO_4	0.14
Nitrogen	$NaNO_3$	0.30
Phosphorus + Nitrogen	as above	as above

Statistical Analysis

Multiple linear regression was used to test the effects of various environmental factors on gross areal productivity. Equations were built using the stepwise procedure.

For the algal bioassay, linear regression was also used to test if the initial slopes (first 4 days) of the fluorescence vs. time curves for the nitrogen treatment and for the control were significantly different from zero.

Two-way parametric and nonparametric ANOVAS (station and series) were used to compare the differences among stations in mean areal and volumetric productivity, and in selected factors (P^Bmax, alpha^B, chl-a, turbidity, extinction coefficient, Secchi depth, and euphotic depth). Series was used as a blocking factor to account for seasonal changes occurring at all stations. The null hypothesis tested was H_o: $\mu 03 = \mu 09 = \mu 17 = \mu 22$. Significant parametric ANOVAS were followed by a Least Significant Difference (LSD) multiple range test. This test determined which means were different from each other ($\alpha = 0.10$). Significant nonparametric ANOVAS were followed by LSD multiple range tests on ranked data at $\alpha = 0.05$.

Correlation analysis was employed to examine the relationships between all factors considered in the determination of areal and volumetric productivity. A non-parametric Spearman correlation coefficient matrix was created for this purpose.

RESULTS

Phytoplankton Productivity vs. Irradiance Assays and Other Laboratory Data

The light saturated rate of photosynthesis per unit chl-a (P^Bmax) ranged from 4.86 to 46.39 mg O_2.mg Chl^{-1}.hr^{-1} with a mean for all stations of 17.84 mg O_2.mg Chl^{-1}.hr^{-1} (Table 3). P^Bmax showed the same trend at all stations from the beginning of the study with a minimum occurring in November and a steady increase thereafter to a maximum in early May (Figure 5). There was a decline in P^Bmax in late May followed by fluctuations in June and July with August 2000 rates slightly higher than rates in August 1999 at the start of the study. Mean P^Bmax was not significantly different among the four stations (two-way parametric ANOVA $p = 0.17$, Table 3).

The initial slope of the photosynthesis-irradiance curve at low light ($alpha^B$) ranged from 20.06 to 98.96 mg O_2.mg Chl^{-1}.E^{-1}.m^2 with a mean for all stations of 47.19 mg O_2.mg Chl^{-1}.E^{-1}.m^2. $Alpha^B$ had a trend similar to P^Bmax from August 1999 until March. Between March and April, $alpha^B$ values at Station 17 declined and, in contrast with the other stations, Station 9 did not show a maximum until late May. $Alpha^B$ was highly significantly correlated to P^Bmax (Spearman rank correlation, $r_s = 0.88$, $p < 0.01$, Table 4).

$Alpha^B$ was significantly different among the four stations (two-way parametric ANOVA $p = 0.02$). A multiple range test (LSD, $\alpha < 0.10$) showed $alpha^B$ at Stations 3 and 22 to be significantly lower than $alpha^B$ at Stations 9 and 17. The discriminatory power of this analysis was found on calculation to be 29%. In other words, means at

Stations 3 and 22 had to be at least 29% lower in order for there to be an observable difference between these stations and Stations 9 and 17.

P^Bmax and alpha^B values, when compared with values from studies similar to this, on other waterbodies, were in the expected range for a turbid, temperate reservoir (Table 5).

The light saturation parameter I_k (P^Bmax/ alpha^B) determines the onset of light saturation, which is often considered the minimum amount of light needed for optimal photosynthesis to take place. I_k had a similar trend to P^Bmax and alpha^B with maximum values for Stations 3, 9, and 22 in early May and for Station 17 in late May. Mean I_k for all stations was 101.63 $\mu E.m^{-2}.s^{-1}$. Respiration at all stations fluctuated seasonally throughout the study, but as was the case with P^Bmax, alpha^B, and I_k, stations exhibited maxima in early May and early June.

Phytoplankton Biomass and Environmental Factors Influencing Phytoplankton Productivity

Chl-a concentrations ranged from 2.21 to 36.79 $mg.m^{-3}$ for all stations with a mean of 12.46 $mg.m^{-3}$. Concentrations started out relatively high in August 1999 and generally declined until March. Station 17 had a peak in concentration in November while Station 3 had a peak in January (Figure 6). Station 3 showed chl-a concentrations that were higher than those at all the other stations during most of the study while Station 17, the Main Lake Zone station, showed the lowest mean chl-a concentration of all the stations. At Station 22, concentrations were decreasing until late spring and only peaked

Table 3. Means (se) of major factors influencing phytoplankton productivity at each station (n=12) or for all stations (n=48) during the August 1999-August 2000 study period. Observed range shown beneath means. The p value beneath some factors represents the significance of the station factor in a 2-way ANOVA (station x sample date). Significant parametric ANOVAS were followed by mean comparison tests (LSD) among station means. Means exhibiting the same superscripted letter are not significantly different from each other (p>0.10). The discriminatory power of this analysis is indicated as the average minimum percent difference in means that could be detected as significant. The symbol (*) distinguishes factors for which nonparametric ANOVAS and mean comparison tests on ranked data were run at $\alpha = 0.05$.

Station	P^B max p=0.17	Alpha^B p=0.02	Ik p=0.90	Respiration	Chl-a* p=0.002	Temperature	Turbidity p<0.01	n"* p<0.01	Secchi p<0.01	Zeu p<0.01
Power		29%			31%		57%	28%	41%	32%
03	16.86 (2.74)	[a]44.48 (4.20)	101.85 (8.49)	-2.29 (0.22)	[a]16.79 (2.38)	22.89 (1.94)	[b]6.50 (0.92)	[a]1.08 (0.08)	[a]0.87 (0.06)	[a]4.46 (0.27)
	6.62-41.13	20.06-75.45	58.7-151.43	-3.49-(-0.96)	9.57-36.79	10.20-32.00	1.29-12.20	0.77-1.61	0.53-1.25	2.86-5.98
09	18.93 (3.39)	[b]51.99 (5.70)	99.51 (9.42)	-3.38 (0.66)	[b]11.51 (2.17)	22.30 (1.91)	[a]3.98 (0.40)	[b]0.74 (0.05)	[b]1.28 (0.09)	[b]6.5 (0.41)
	6.58-46.39	24.43-79.20	49.31-179.72	-7.48-(0.900)	3.49-27.91	10.40-32.00	1.29-6.12	0.49-1.14	0.75-1.85	4.04-9.21
17	19.39 (3.44)	[b]51.47 (6.97)	100.80 (7.78)	-3.19 (0.54)	[b]9.94 (2.26)	21.67 (1.85)	[a]2.74 (0.31)	[c]0.59 (0.06)	[c]1.94 (0.20)	[c]8.57 (0.75)
	7.65-45.17	24.27-98.96	62.81-147.52	-6.08-(-1.14)	2.21-22.64	10.30-29.90	1.29-5.56	0.32-1.12	1.05-3.25	4.11-14.39
22	16.19 (2.52)	[a]40.80 (3.43)	104.36 (9.16)	-2.60 (0.63)	[b]11.64 (1.59)	22.56 (1.87)	[b]6.21 (0.86)	[b]0.89 (0.07)	[a]0.98 (0.06)	[a]5.45 (0.32)
	4.86-36.59	20.75-54.98	61.31-184.87	-8.11-0.18	2.31-18.80	10.90-31.12	3.43-13.93	0.70-1.39	0.55-1.25	3.31-6.58
all stations	17.84 (1.48)	47.19 (2.64)	101.63 (4.23)	-2.86 (0.27)	12.46 (1.09)	22.35 (0.92)	4.85 (0.40)	0.83 (0.04)	1.27 (0.08)	6.25 (0.32)
	4.86-46.39	20.06-98.96	49.31-184.87	-8.11-0.18	2.21-36.79	10.20-32.00	1.29-13.93	0.32-1.61	0.53-3.25	2.86-14.39

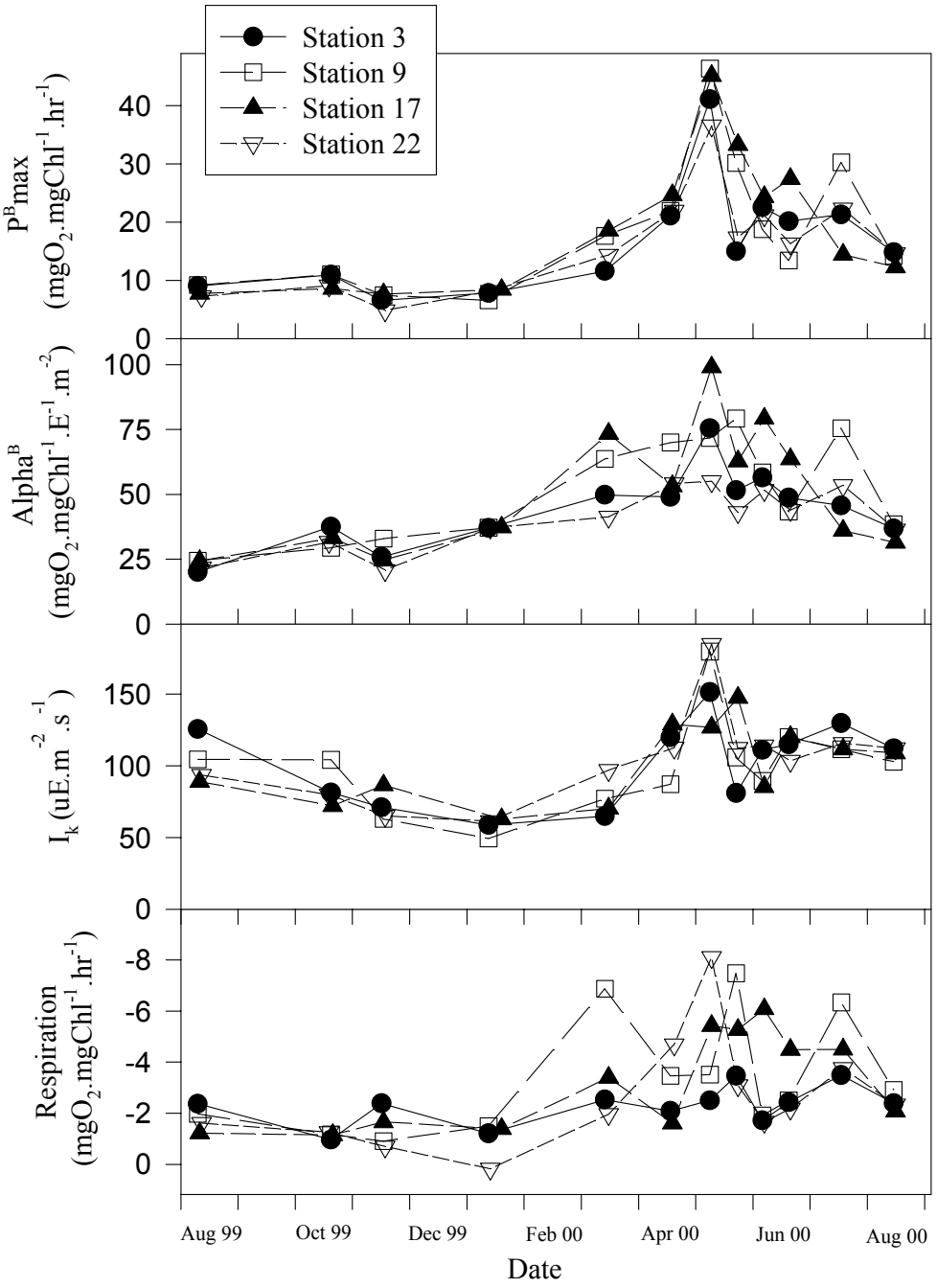

Figure 5. Seasonal pattern of variables determined from the laboratory assays of production vs. irradiance for each station.

Table 4. Spearman Correlation Coefficient matrix for all variables included in the study. Values presented are Spearman correlation coefficient and associated p value. N = 48.

	ALPHA	CHLA	EXT COFF	TURB	SECCHI	PMAX	ZEU	TEMP	RESP	IK	GP AREAL	GPVOL	PAR
ALPHA	1.00	-0.79	-0.24	-0.08	0.25	0.88	0.24	-0.26	-0.69	0.36	0.06	0.03	-0.01
		<0.01	0.09	0.57	0.09	<0.01	0.09	0.08	<0.01	0.01	0.66	0.83	0.93
CHLA	-0.79	1.00	0.48	0.21	-0.45	-0.68	-0.48	0.47	0.59	-0.25	0.26	0.43	0.11
	<0.01		<0.01	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.07	0.01	0.45
EXTCOFF	-0.24	0.48	1.00	0.82	-0.80	-0.20	-1.00	0.11	0.28	-0.10	-0.24	0.28	-0.22
	0.09	<0.01		<0.01	<0.01	0.17	<0.01	0.46	0.06	0.49	0.10	0.05	0.14
TURB	-0.08	0.21	0.82	1.00	-0.73	-0.08	-0.82	-0.09	0.18	-0.10	-0.35	0.13	-0.25
	0.57	0.15	<0.01		<0.01	0.57	<0.01	0.53	0.23	0.51	0.01	0.39	0.09
SECCHI	0.25	-0.45	-0.80	-0.73	1.00	0.16	0.80	-0.21	-0.16	0.02	0.08	-0.37	0.11
	0.09	<0.01	<0.01	<0.01		0.27	<0.01	0.16	0.26	0.90	0.60	0.01	0.47
PMAX	0.88	-0.68	-0.20	-0.08	0.16	1.00	0.20	0.03	-0.73	0.72	0.32	0.28	0.27
	<0.01	<0.01	0.17	0.57	0.27		0.17	0.85	<0.01	<0.01	0.03	0.05	0.06
ZEU	0.24	-0.48	-1.00	-0.82	0.80	0.20	1.00	-0.11	-0.28	0.10	0.24	-0.28	0.22
	0.09	<0.01	<0.01	<0.01	<0.01	0.17		0.46	0.06	0.49	0.10	0.05	0.14
TEMP	-0.26	0.47	0.11	-0.09	-0.21	0.03	-0.11	1.00	0.03	0.36	0.68	0.68	0.58
	0.08	<0.01	0.46	0.53	0.16	0.85	0.46		0.84	0.01	<0.01	<0.01	<0.01
RESP	-0.69	0.59	0.28	0.18	-0.16	-0.73	-0.28	0.03	1.00	-0.51	-0.31	-0.12	-0.35
	<0.01	<0.01	0.06	0.23	0.26	<0.01	0.06	0.84		0.01	0.03	0.41	0.02

Table 4. (Continued)

	ALPHA	CHLA	EXT COFF	TURB	SECCHI	PMAX	ZEU	TEMP	RESP	IK	GP AREAL	GPVOL	PAR
IK	0.36	-0.25	-0.10	-0.10	0.02	0.72	0.10	0.36	-0.51	1.00	0.52	0.51	0.52
	0.01	0.08	0.49	0.51	0.90	<0.01	0.49	0.01	0.01		<0.01	<0.01	<0.01
GP AREAL	0.06	0.26	-0.24	-0.35	0.08	0.32	0.24	0.68	-0.31	0.52	1.00	0.81	0.75
	0.66	0.07	0.10	0.01	0.60	0.03	0.10	<0.01	0.03	<0.01		<0.01	<0.01
GPVOL	0.03	0.43	0.28	0.13	-0.37	0.28	-0.28	0.68	-0.12	0.51	0.81	1.00	0.56
	0.83	0.00	0.05	0.39	0.01	0.05	0.05	<0.01	0.41	<0.01	<0.01		<0.01
PAR	-0.01	0.11	-0.22	-0.25	0.11	0.27	0.22	0.58	-0.35	0.52	0.75	0.56	1.00
	0.93	0.45	0.14	0.09	0.47	0.06	0.14	<0.01	0.02	<0.01	<0.01	<0.01	

Table 5. Comparison of P^Bmax and alpha^B values for different water bodies.

Location	Year	P^Bmax (mg C.mg Chl^{-1}.hr^{-1})	alpha^B (mg C.mg Chl^{-1}.E^{-1}.m^2)	Comments	Reference
Bedford Basin, Nova Scotia	1975	2.04-8.37	9.66-31.40	Spring/summer (May-July) day-to-day variations in photosynthetic parameters measured over a 70-day period	Cote and Platt (1983)
Northfrisian Wadden Sea, Germany	1995-1996	0.8-9.9	1.94-10.83	Primary production measured March 1995 to December 1996	Tillmann, Hesse, and Colijn (2000)
Lake Ontario, Canada	1987-1992	Station 41: 0.36-7.53 Station 81: 0.50-7.43	Station 41: 0.64-13.45 Station 81: 0.96-11.69	Two stations; primary production measured May-late October	Millard, Myles, Johannsson, and Ralph (1996)
Oligotrophic Shield Lakes, Canada	1997	3.5	9.2	Median values for 12 lakes; primary production and community respiration measured May-Oct 1997	Carignan, Planas, and Vis (2000)
Tomhannock Reservoir, New York	1991-1992	0.62-20.9	0.73-20.2	Mean for three stations; primary production measured May 1991-Oct 1992	Melcher (1994)
Lake Texoma, Texas-Oklahoma	1999-2000	1.52-14.50	6.27-30.93	Mean for four stations; primary production measured Aug 1999-Aug 2000	Present study
Lake Ray Roberts, Texas	1994	2.8-7.8	8.7-19.1	Single station, spring and summer values	Doyle (unpublished data)

in the summer. Chl-a concentrations were significantly correlated to extinction coefficients and temperature and significantly inversely correlated to P^Bmax and Secchi depth ($p < 0.01$, Table 4)

Chl-a was highly significantly different among the four stations (two-way nonparametric ANOVA $p = 0.002$). A multiple range test on ranked data (LSD, $\alpha < 0.05$) revealed that Station 3 was significantly different from all the other stations while stations 9, 17, and 22 were not significantly different from each other with respect to this parameter. The minimum observable difference between these means was 31%.

Temperatures mirrored each other closely at all stations throughout the duration of the study with maxima in the summer, a steady decline in the fall and winter, followed by a steady rise through spring to the summer (Figure 7). The mean temperature for all the stations was 22.35 ^oC but ranged from 10.20 ^oC to 32.00 ^oC.

Turbidity values followed the same trend of rising from August to October, followed by a decline in November 1999, at all stations (Figure 8). After November, turbidity at Station 3 increased to a maximum in March, another small peak in early May, and then a decline throughout the summer. Station 22 had a sharp peak in turbidity values in early May followed by an equally sharp decline towards the end of May followed by another smaller peak in June with a leveling off in July and August. Station 3 had the highest mean turbidity values, followed closely by Station 22 (Table 3), while Station 17 had the least mean turbidity.

As is to be expected of a reservoir, turbidity was highly significantly different among the stations (parametric two-way ANOVA, $p < 0.01$). Multiple range comparison

($\alpha = 0.10$) showed that turbidity at Stations 3 and 22 was significantly different from that at Stations 9 and 17 and the minimum observable difference between the means was calculated as 57%.

Trends in light extinction closely mimicked those of turbidity for all stations throughout the duration of the study (Figure 8). Light extinction was also highly significantly different among the four stations (nonparametric two-way ANOVA, $p < 0.01$). Multiple range comparison on ranked data (LSD, $\alpha = 0.05$) showed that Stations 9 and 22 were not significantly different from each other with respect to this parameter and the minimum observable difference between the means was 28%. Station 17, as expected of the Main Lake Zone had the highest mean Secchi depth of all the stations while Station 3 had the lowest (Table 3). Secchi depth was highly significantly correlated to extinction coefficient (Spearman rank correlation, $r_s = -0.80$, $p < 0.01$)

Euphotic zone depth was consistently greatest at Station 17 and lowest at Station 3 for the duration of the study (Figure 8).

PAR values exhibited the same seasonal trend as temperatures, showing a decline from summer to fall and winter and a steady rise through spring, again peaking in summer. Mean PAR calculated from averages taken around the sampling dates was 44.04 E m^{-2} day^{-1}.

Estimates of Gross Areal and Volumetric Productivities

Annual areal gross productivity for all stations, assuming a photosynthetic quotient of 1.2 (1.2 moles of oxygen produced per mole of carbon dioxide reduced)

(Wetzel and Likens, 1991), ranged from 594 g $C.m^{-2}.yr^{-1}$ at Station 22 to 753 g $C.m^{-2}.yr^{-1}$ at Station 3 (Table 6). Areal productivity tended to be high in the summer at all stations at the start of the study but decreased in the fall and winter and rose in spring. There was, however, a small peak at Station 3 in December and Station 17 in November. Station 22 exhibited a slightly different trend from the other stations. In early May, gross areal productivity at this station declined but thereafter increased in July 2000 to almost double the productivity at the start of the study in August 1999 (Figure 9). As is to be expected, gross areal productivity at all stations seemed to increase and decrease with PAR values (Figure 9).

Gross areal productivity was highly significantly correlated to PAR (Spearman rank correlation, $r_s = 0.75$, $p < 0.01$), was significantly correlated to temperature (Spearman rank correlation, $r_s = 0.68$, $p < 0.01$), and was less (inversely) correlated to water clarity as reflected by turbidity (Spearman rank correlation, $r_s = -0.35$, $p = 0.01$). Areal productivity was not significantly correlated to algal biomass (Spearman rank correlation, $r_s = 0.26$, $p = 0.07$).

Gross volumetric productivity showed a similar seasonal trend to gross areal productivity (Figure 10). The depth profile of gross volumetric productivity for Station 3 for August 1999 and January 2000 showed that productivity was mostly confined to the upper 4 m of the water column at these two periods (Figure 11). Maximum gross volumetric productivity on August 12, 1999 (summer), was almost 2.3 times greater than it was on January 13, 2000 (winter), for this station.

The depth profile for Station 17 for August 1999 and January 2000 (Figure 11) showed that productivity was about 1.8 times greater on August 12, 1999, than on January 13, 2000.

Comparison Among Stations

Mean gross areal productivity was significantly different among the four stations (two-way parametric ANOVA $p = 0.02$). A Least Significant Difference (LSD) multiple range comparison test ($\alpha = 0.10$) revealed that areal gross productivity at Station 22 was significantly different from that at all the other stations. The minimum observable difference between the means was 30%.

Mean gross volumetric productivity was also significantly different among the four stations (two-way parametric ANOVA $p << 0.10$). A multiple comparison test indicated that gross volumetric productivity at Station 3 was significantly different from that at all other stations, while volumetric productivity at Station 22 was not significantly different from that at Stations 9 and 17. The minimum observable difference between the means was 38%.

A multiple regression yielded the following statistically significant ($F = 36.78$, $p = 0.000$, $R^2 = 0.774$) model for gross areal productivity: $gpm^2 = -1.35332 + 0.23733*temp + 0.108704*par – 2.81702*ext + 0.071262*chl\text{-}a$. For gross volumetric productivity, multiple regression also yielded a statistically significant model ($F = 18.25$, $p = 0.000$, R^2

Table 6. Annual and daily gross and net productivity values for the present study in carbon units. Values in oxygen units (g $O_2.m^{-2}.d^{-1}$) are in parentheses.

	Gross annual productivity ($gC.m^{-2}.yr^{-1}$)	Gross daily productivity ($gC.m^{-2}.d^{-1}$)	Net annual productivity ($gC.m^{-2}.yr^{-1}$)	Net daily productivity ($gC.m^{-2}.d^{-1}$)
Station 3	753 (2450)	2.09 (6.70)	326 (1059)	0.91 (2.89)
Station 9	751 (2441)	2.09 (6.67)	285 (928)	0.79 (2.54)
Station 17	708 (2302)	1.97 (6.29)	267 (869)	0.74 (2.38)
Station 22	594 (1925)	1.64 (5.26)	308 (997)	0.85 (2.73)

= 0.629). The model was: gpm^3 = -1.81962 + 0.06713*temp + 0.02834*par + 0.02247*chla + 1.11154*ext.

Algal Bioassay

Both Stations 17 and 22 showed increases in phytoplankton abundance for both treatments that included an addition of phosphorus (Figure 12). At both stations, groups treated with just phosphorous and those treated with both phosphorus and nitrogen showed very strong increases in phytoplankton abundance while controls or groups treated with just nitrogen showed little or no response over time.

Regression analysis was performed to determine whether the initial slopes of the first 4 days of the control and nitrogen curves for Stations 17 and 22 were significantly different than zero. Slopes relating fluorescence with no treatment and with nitrogen addition to time in days after commencement of the assay for Station 22 were significantly different from zero. The analysis produced statistically significant models for controls:

fluorescence = 2.474 + 0.6076*day ($t = 3.55$, $p = 0.002$, adjusted $R^2 = 37.90\%$), and

nitrogen: fluorescence = 1.786 + 0.736*day ($t = 6.53$, $p = 0.000$, adjusted $R^2 = 68.67\%$). Slopes relating fluorescence with no treatment and with nitrogen addition to time in days after commencement of the assay for Station 17 were not significantly different from zero ($p > 0.10$).

DISCUSSION

Temporal Variability in Areal and Volumetric Phytoplankton Productivity

Multiple regression showed that the chief factors affecting areal phytoplankton productivity in Lake Texoma were temperature, PAR, chl-a, and water clarity as reflected by turbidity (light extinction can be considered a measure of turbidity).

Summer areal net productivity estimates on a station-by-station basis were lower than the estimate of mean net primary productivity for Lake Texoma of 2628 mg C $m^{-2}.d^{-1}$ for fall and summer 1978 given by Ellis (1980) (Table 7), and higher than the summer 1979 and 1980 estimates of 934 mg C $m^{-2}.d^{-1}$ recorded by Kimmel (Wetzel, 1983). Observations of the seasonal behavior of chl-a in the current study did not fully correspond with McCullough's observations of standing crop trends in his study (McCullough, 1978). However, seasonal behavior of chl-a did conform generally to the trends found by Gibbs (1998) and Atkinson et al., (1999). Attenuation, Secchi depth, and euphotic depth showed the same trends spatially as those described by Rolbiecki (1998).

A comparison of annual monthly mean stream flow data for the period during which this study was conducted (August 1999 to August 2000), with data for the two years prior to this and with the historical average (Figure 13) revealed that 1999-2000 was a very dry year. Monthly stream flow during this period was 47% lower than the historical average. Consequently, hydrologic effects of rainfall and inflows on

Table 7. Summary of reservoir phytoplankton productivity estimates. Productivity values represent the mean daily production for the entire year or growing season, unless noted otherwise. Asterisks indicate average values for two or more annual production estimates. Lake Texoma data reflect the annual mean. Lake Texoma average summer values (Aug-Sept 1999 and Jun-Aug 2000 data only) are in parentheses. Trophic state categories, as indicated by ^{14}C method estimates, are those of Likens (1975) and Wetzel (1983). Table adapted from Kimmel (1990).

Reservoir, Location	Mean daily production			Reference
	Year	(mg C $m^{-2}d^{-1}$)	Comments	
OLIGOTROPHIC 50-300 mg C $m^{-2}d^{-1}$				
Tuttle Creek, Kansas	1970, 71	67	^{14}C; highly turbid, light-limited system	Marzolf and Osborne (1971)
Sam Rayburn, Texas	1977-78	102	^{14}C	Lind (1979b)
Smallwood, Labrador, Canada	1974, 75	138*	^{14}C	Ostrofsky (1978), Ostrofsky and Duthie (1978)
Canyon, Texas	1976	184	^{14}C	Hannan et al. (1981)
Nickajack, Tennessee	1973	235	^{14}C, summer estimates	Placke and Poppe (1980)
MESOTROPHIC 250-1,000 mg C $m^{-2}d^{-1}$				
Francis Case, South Dakota	1968	260	Net O_2 change, summer estimates	Martin and Novotny (1975)
Isabella, Michigan	1977-78	424	Net O_2 change, seasonal estimates	Groeger (1979)
North Lake, Texas	1976	521	^{14}C	Stuart and Stanford (1979)
Cheat, West Virginia	1971	695	^{14}C	Volkmar (1972)
Waco, Texas	1968, 1977-78	814*	^{14}C	Kimmel and Lind (1972), Lind (1979)
Pena Blanca, Arizona	1959-61	899	Gross pelagic production by O_2 change and estimates from chlorophyll data	McConnell (1963)

Table 7. (Continued)

Texoma, Oklahoma-Texas	1999-00	742 (1151)	Net O_2 change estimated from station in main lake body; (summer estimates in parentheses)	Present Study
	1999-00	793 (1418)	Net O_2 change estimated from station in Red River transition zone of reservoir	
	1999-00	852 (1310)	Net O_2 change estimated from station in Washita River zone of reservoir	
	1999-00	905 (1446)	Net O_2 change estimated from station in Red River zone of reservoir	
Texoma, Oklahoma-Texas	1979, 80	934	^{14}C, summer estimates	B.L. Kimmel (unpubl.data)
Douglas, Tennessee	1969	940	^{14}C	Taylor (1971)
EUTROPHIC >1000 mg C $m^{-2}d^{-1}$				
Texoma, Oklahoma-Texas	1978	2628	^{14}C summer and fall estimates; midlake sample	Ellis (1980)
Canyon Ferry, Montana	1958	1125	Net O_2 change, April - September	Wright (1958, 1959, 1960)
Moss, Texas	1976	1302	^{14}C	Silvey and Stanford (1978)
Long Lake, Washington	1972, 73	1903	Estimated from chlorophyll and light data after Ryther and Yentsch (1957), July - March	Soltero et al. (1975)
Stagecoach, Nebraska	1969, 70	3975*	^{14}C summer estimates	Anderson and Hergenrader (1973)

Modified from Wetzel (1983).

productivity were thought to have been minimal within this time interval. The streamflow data were obtained from the United States Geological Survey website and historical averages were calculated using all data available from 1924 to 2000.

Areal productivity decreased in the fall and winter with the seasonal decline in temperature and PAR values. In February, however, when temperatures and PAR values began to climb, areal productivity generally remained low. At Station 3 there was a slight increase in productivity in January probably as a result of a peak in chl-a abundance at this same time. Station 17 exhibited a peak in productivity in November even though temperatures and PAR values were declining. This peak was again probably attributable to a peak in chl-a concentration during this month. An increase in water clarity as a result of a decrease in turbidity also may have contributed to this peak in productivity, however, all other stations also showed an increase in water clarity in November. At all stations except Station 22, areal productivity began to climb substantially in late March at the onset of spring and exhibited peaks coinciding with spring and summer peaks in chl-a. At Station 22, areal productivity did not begin to climb until May because it was not until then that chl-a showed a definite increase.

Chl-a concentration showed a four-fold increase between the first May sampling date and the second May sampling date and almost doubled between the second May sampling date and the first June sampling date (Figure 6). This increase in chl-a concentration brought about a large spurt in areal productivity from May continuing on through the summer. By July of 2000 areal productivity at Station 22 was almost twice as

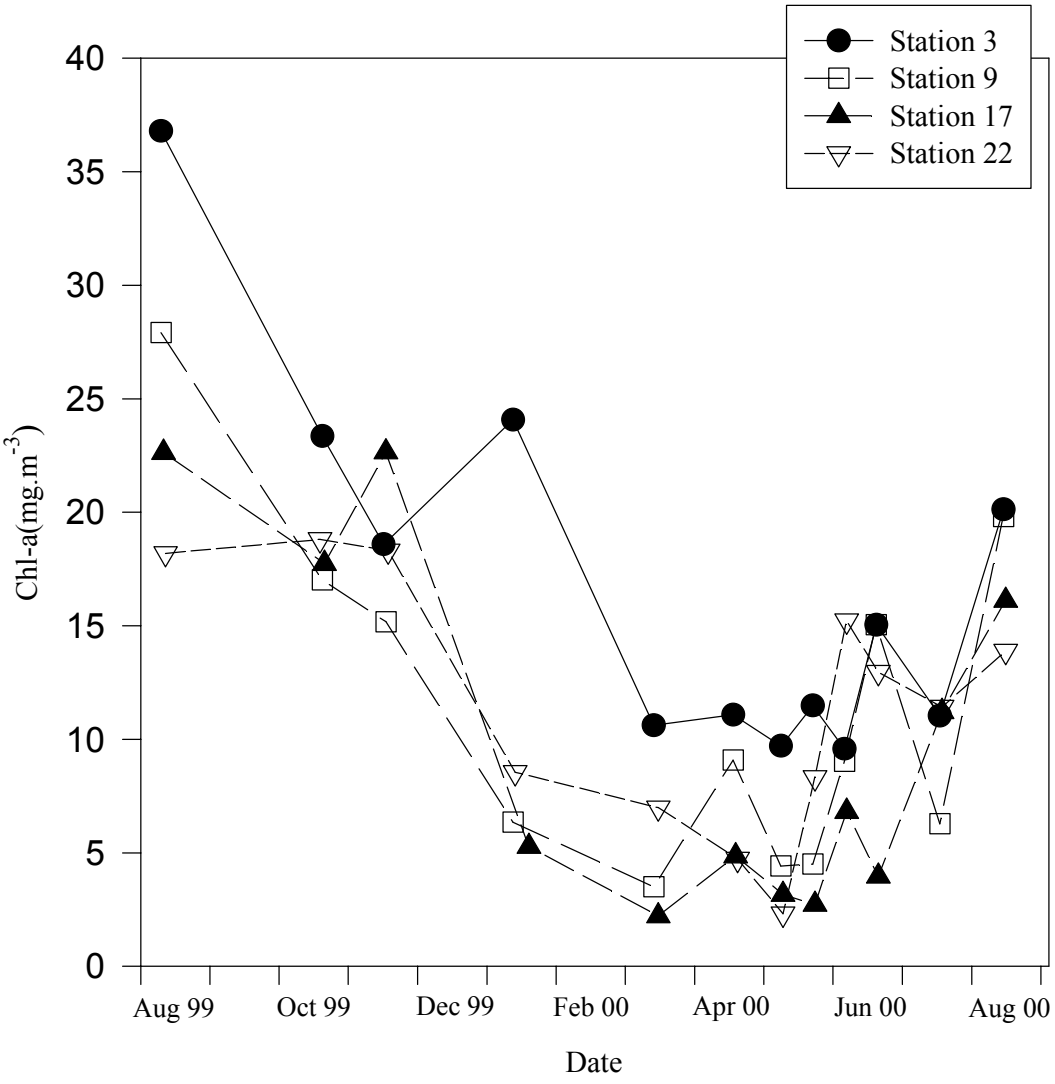

Figure 6. Seasonal pattern of chlorophyll-a at each station during the study period.

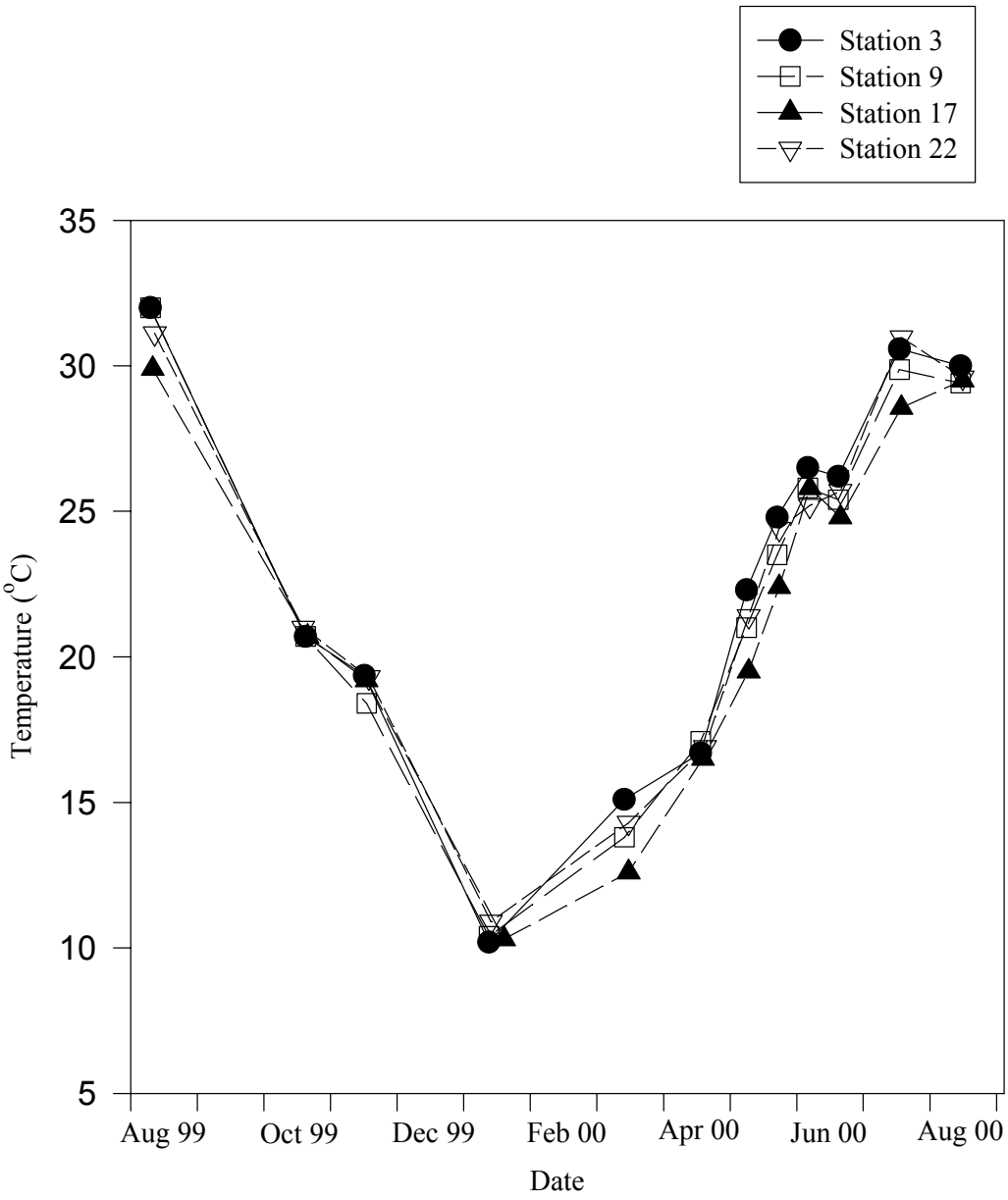

Figure 7. Seasonal pattern of temperature at each station during the study period.

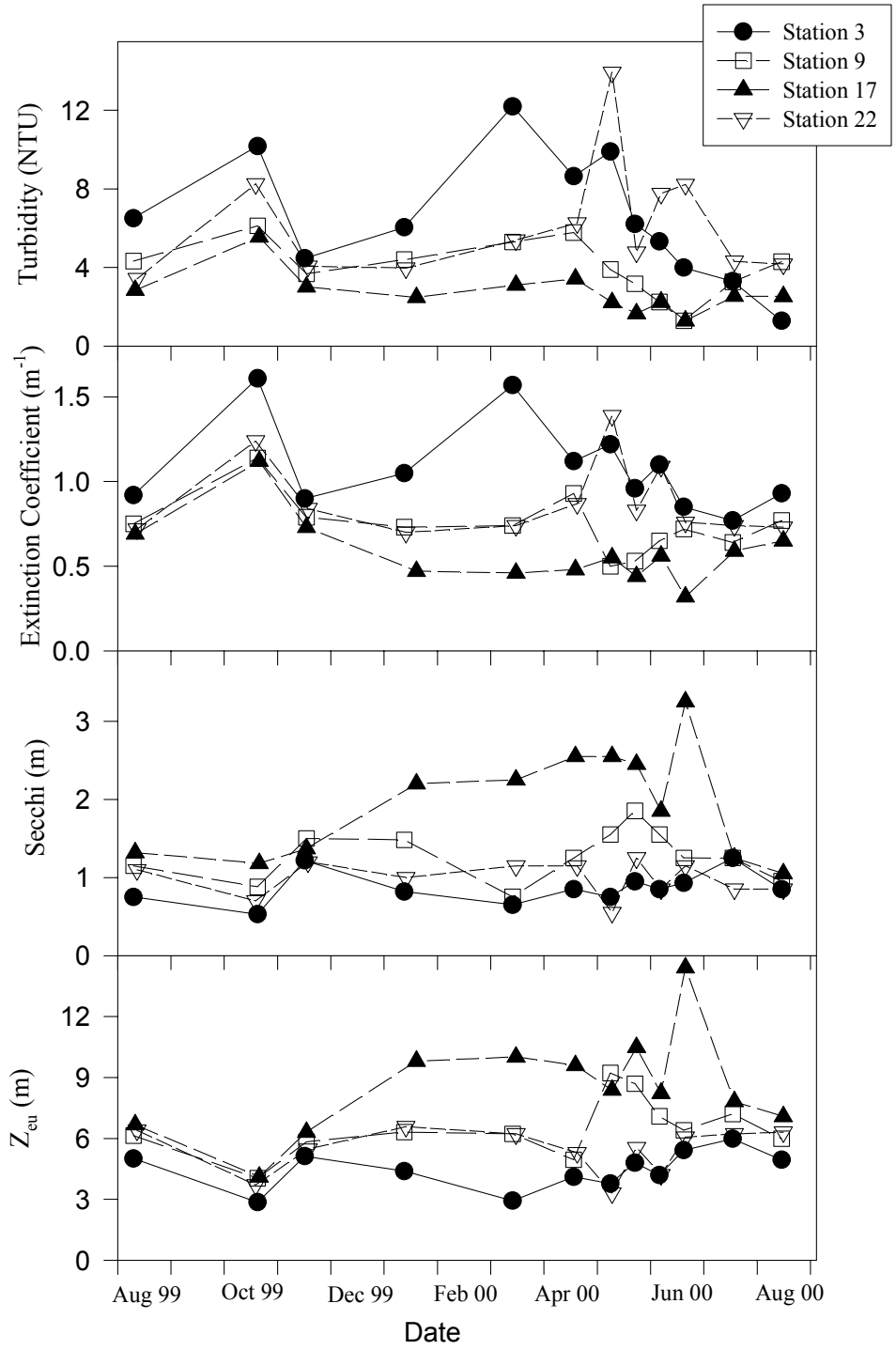

Figure 8. Seasonal pattern of variables related to light penetration at each station during the study period.

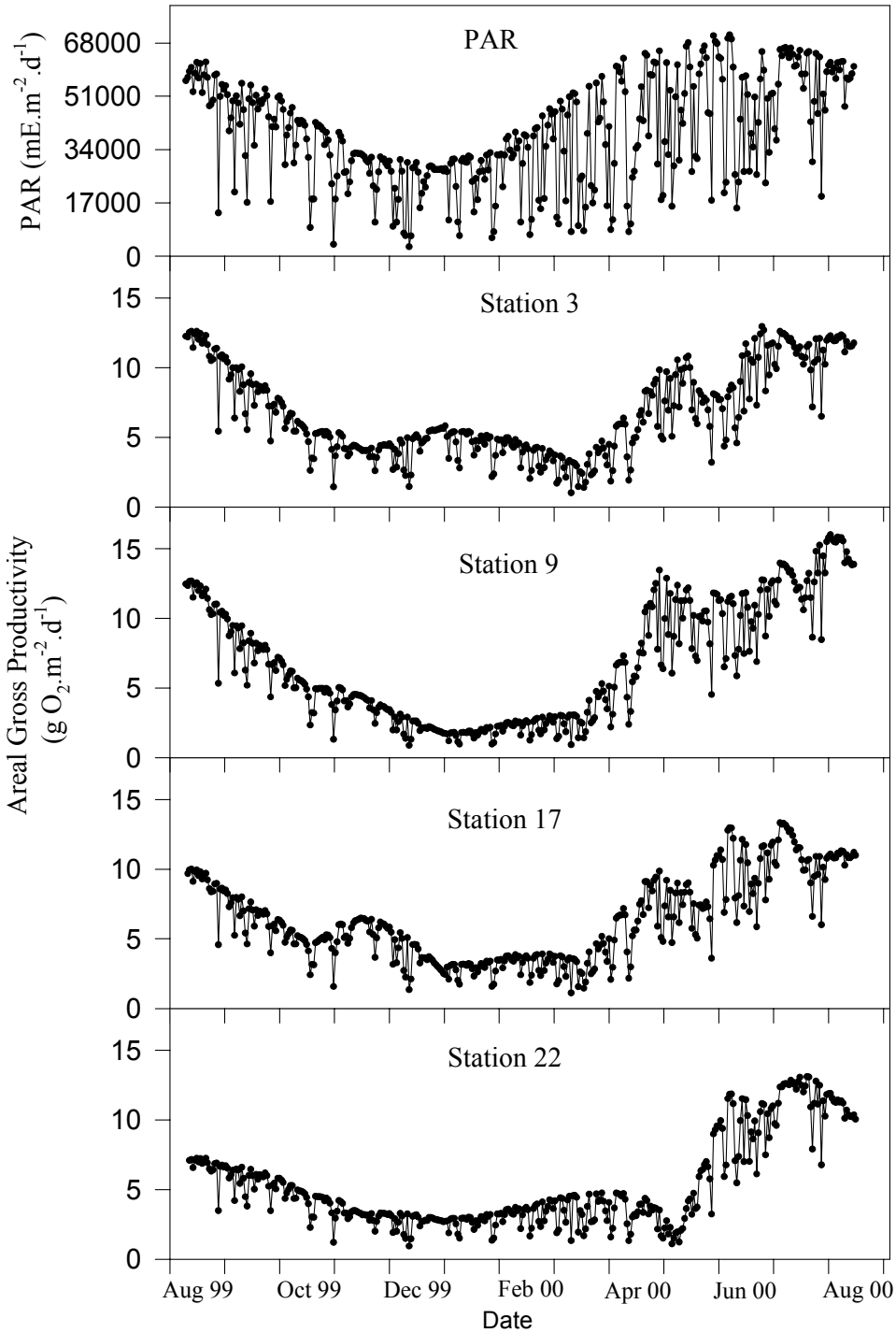

Figure 9. Daily total incident photosynthetically available radiation (PAR, top panel) through the study period. Estimated areal gross photosynthetic productivity at each station for each day during the study period.

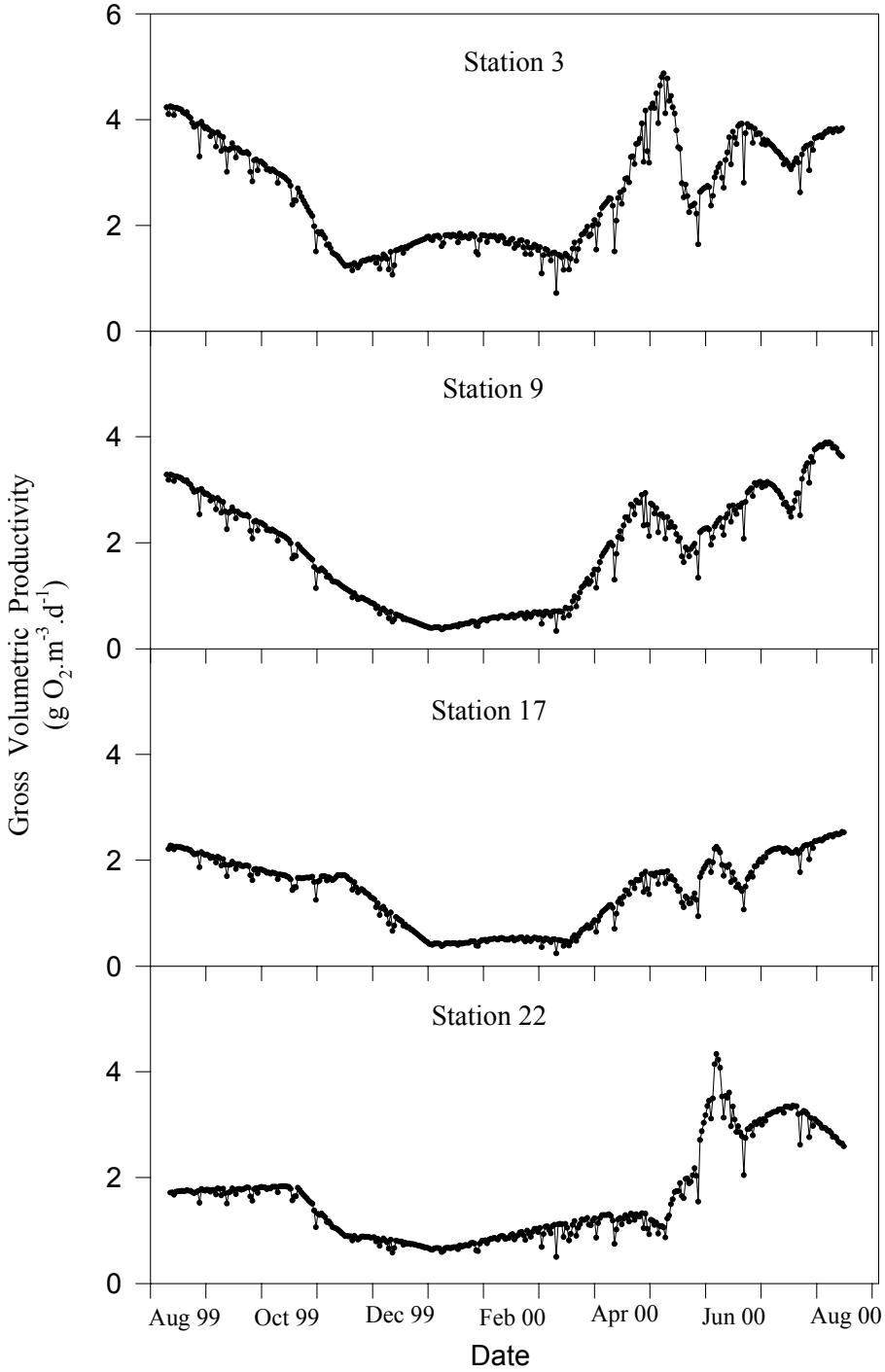

Figure 10. Daily maximum volumetric photosynthetic productivity at each station through the study period.

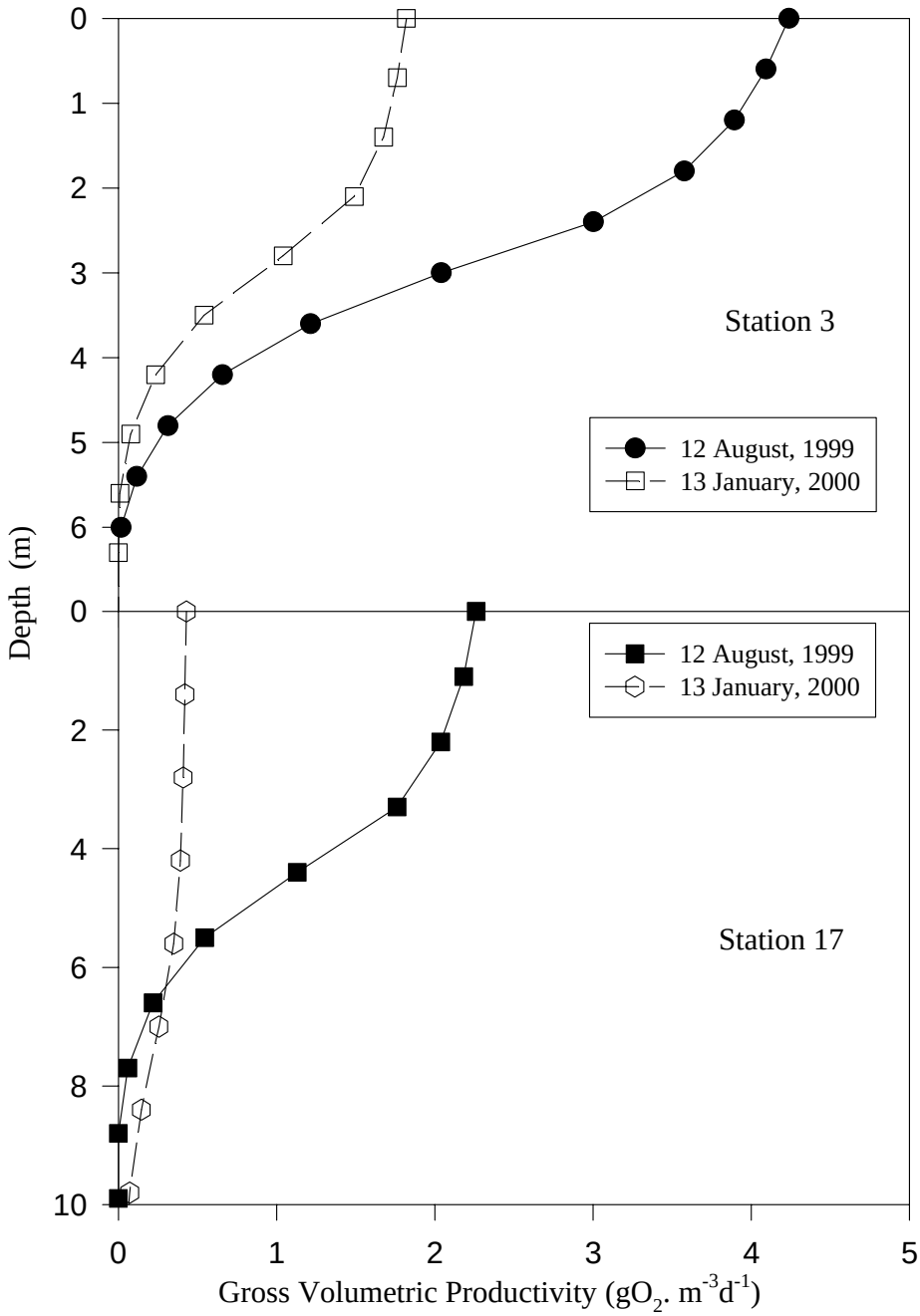

Figure 11. Vertical depth profile of gross productivity at Station 3 (most turbid station) and Station 17 (main lake body and least turbid station) in winter (open symbols) and summer (closed symbols).

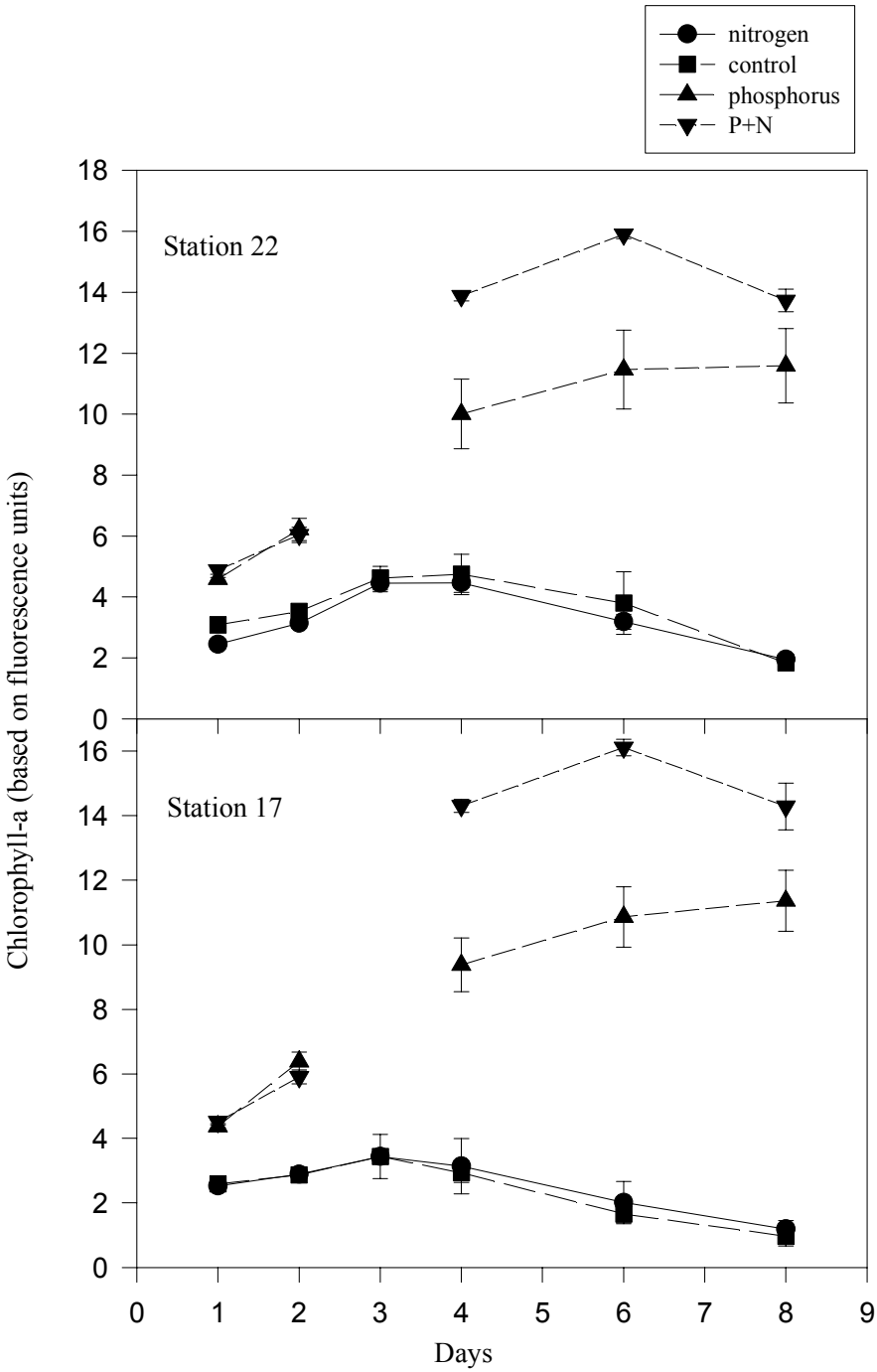

Figure 12. Results of algal bioassays for Station 22 (top) and Station 17(bottom) in August 2000.

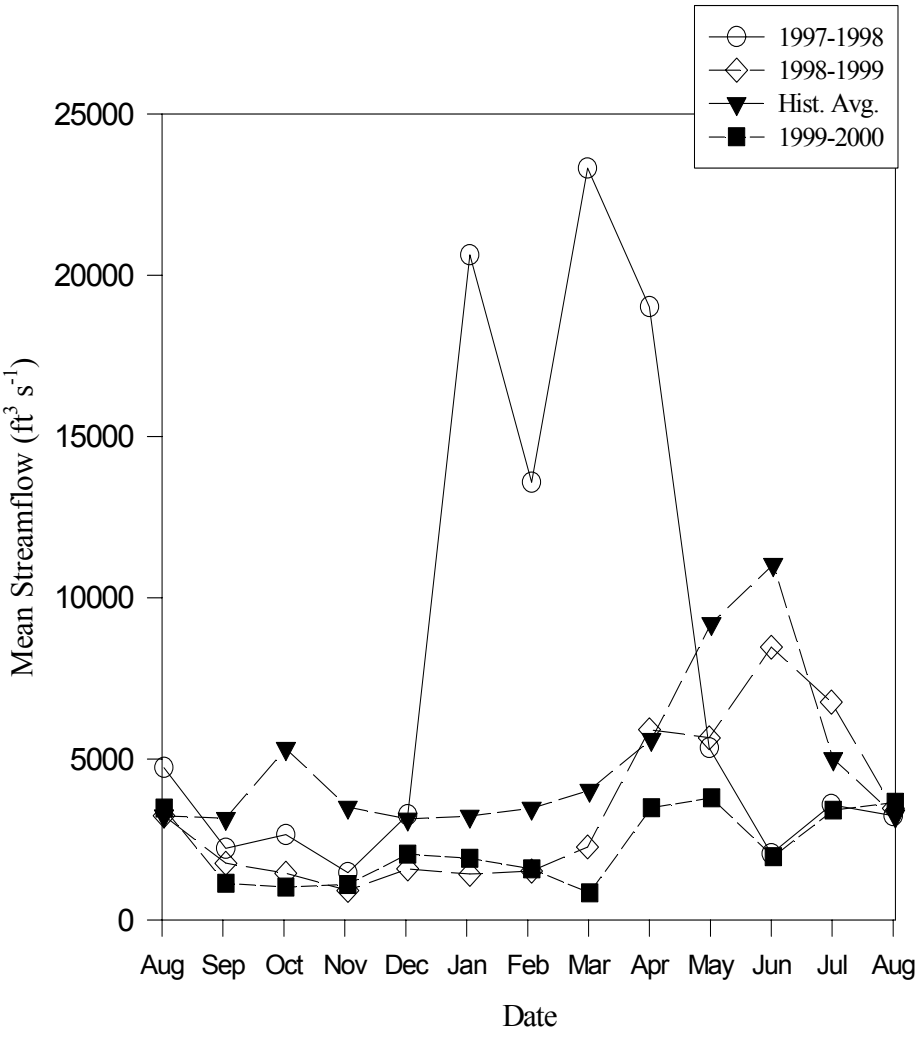

Figure 13. Mean monthly streamflow for Red River at Denison Dam for the years 1997-2000. The historical average is included.

high as it was at the start of the study in August 1999. At the same time as chl-a concentration was increasing between April and the first May sampling date, turbidity at Station 22 also increased dramatically (Figure 8). Hence there was a decrease in light availability at the time of the surge in areal productivity. This suggests that, during this time, chl-a and not turbidity was the major determinant of areal productivity.

Volumetric productivity showed similar seasonality to areal productivity and displayed more distinct peaks in the spring and summer. A multiple regression model showed that most of the chief factors affecting areal productivity also affected volumetric productivity.

Spatial Variability in Areal and Volumetric Phytoplankton Productivity

Since PAR and temperature were virtually similar at all stations, throughout the duration of the study, spatial variability must have been controlled by factors other than these. Longitudinal differences in light penetration and algal biomass were the most likely cause of the significant difference in areal productivity at the four stations.

According to Kimmel et al (1990) as mentioned earlier, longitudinal gradients in reservoirs create spatial heterogeneity in phytoplankton productivity and biomass. They also divide a typical reservoir into distinguishable riverine, transition, and lacustrine zones. The riverine zone normally exhibits higher light extinction compared to downstream areas of the reservoir and abiogenic turbidity often limits light penetration, thereby limiting the thickness of the photic layer. Areal primary productivity is often light-limited in this zone.

The transition zone will normally have higher phytoplankton productivity and biomass and increased light penetration in conjunction with other factors that make both light and nutrients available for algal photosynthesis. This zone is often the most fertile region of the reservoir.

The lacustrine zone occurs nearest the dam and usually has higher water transparency and a deeper photic layer. Volumetric productivity of the photic zone is reduced (often by nutrient limitation) during most of the growing season and is supported in good part by *in situ* nutrient cycling rather than by advected nutrients (Kimmel et al., 1990).

Stations 3 and 22 in the Red River and Washita River Zones of the lake, respectively, were riverine stations. Station 3 had the highest annual areal productivity (753 g $C.m^{-2}.yr^{-1}$) and mean turbidity and the shallowest photic zone of the four stations (Table 3). Station 22, on the other hand, had the lowest areal productivity (594 g C $m^{-2}.yr^{-1}$) but came a close second to Station 3 in mean turbidity and photic zone depth.

The difference in annual productivity between these two relatively turbid and light limited riverine stations may be explained by a difference in chl-a concentrations. Mean chl-a concentration at Station 3 was 16.79 mg m^{-3} while mean concentration at Station 22 was over 30 % lower at 11.64 $mg.m^{-3}$. The results of the two-way ANOVA, which found that chl-a was significantly different at Station 3 than at all other stations, support the above speculation.

Annual areal productivity at the transition station (Station 9) was 751 $gC.m^{-2}.yr^{-1}$. This station was expected to be the most fertile and have higher productivity, increased

light and increased biomass. Although mean turbidity at this station was lower than at Stations 3 and 22 indicating increased light availability, productivity was again limited by algal biomass as reflected in chl-a concentrations. Mean chl-a concentration at this station was 11.51 mg m^{-3}.

Station 17, which was in the Main Lake Zone, was the least turbid of all the stations, and had the deepest photic zone. Annual areal productivity at this station was 708 g $C.m^{-2}.yr^{-1}$. Chl-a concentration was lowest here compared to all the other stations, in agreement with Gibbs's findings. A reduction in volumetric productivity was expected at this station because of nutrient limitation. The volumetric productivity depth profile for the station (Figure 11) showed that volumetric productivity was indeed less here than it was at Station 3, although turbidity, photic zone, and Secchi depth values were all optimal for increased light availability. Algal biomass as reflected in chl-a concentrations may have been limited by nutrient availability.

Observations of the current study regarding relationships between chl-a and primary productivity did not correspond with Ellis's findings, which showed that primary productivity values were higher during October while greater plankton densities, as can be estimated by chl-a, occurred during the summer.

Nutrient Parameters Limiting Phytoplankton Biomass

Though there were increases in phytoplankton abundance for treatments that included addition of phosphorus, for Station 22, the initial slope of the curve relating fluorescence to time for the controls and for nitrogen was significantly different from

zero. In other words, there were sufficient nutrients in the water from Station 22 to support initial growth of the *Selenastrum* culture. This suggests that in the natural system (the reservoir), phytoplankton at this station were initially limited by light availability and only secondarily limited by phosphorus because controls with no treatment showed an increase in algal abundance when exposed to ample light in the laboratory. Samples treated with nitrogen also showed an increase in algal abundance, though this increase was not much different from that exhibited by the controls, showing that after light availability, phosphorus was the factor limiting phytoplankton abundance at this station. This finding of light limitation is consistent with the fact that Station 22 is one of the riverine stations and is thus more turbid than stations in the Main Lake Zone.

Station 17, the Main Lake Zone station, and the station with the greatest water clarity, also showed increases in phytoplankton abundance for treatments that included addition of phosphorus, but the initial slopes of the curves relating fluorescence to time for the controls and for nitrogen were not different from zero ($p > 0.10$). This indicated that, at this station, phytoplankton were limited by phosphorus, since the controls with no treatment did not show an appreciable increase in algal abundance when exposed to ample light conditions in the laboratory. Likewise, samples from this station treated with nitrogen did not show a significant increase in algal abundance, indicating that phosphorus was most likely the limiting factor. As mentioned earlier, a reduction in volumetric productivity was expected at this station because of lower algal biomass related to nutrient limitation. The results of the bioassay support the notion that this station was nutrient limited.

These findings concur with Gibbs's (1998) statement regarding the likelihood of nutrient limitation dominating in the open water Main Lake Zone, while light limitation determined chl-a concentrations in the river zones.

Dissolved ortho-phosphorus (PO_4) data obtained from the ongoing water quality study, for Stations 3, 9, 17, and 22, throughout the study period (Table 8), showed ortho-phosphorus levels at these stations constantly close to, at, or below the minimum detection limit (0.02 $mg.L^{-1}$) for this factor, except in August 1999 when levels were slightly higher. These low concentrations of ortho-phosphorus at the study stations again support the findings of the current investigation that phosphorus was the nutrient limiting productivity in August 2000 at Stations 17 and 22 and suggest that this was the case at Stations 3 and 9 also. The slightly higher concentrations of ortho-phosphorus in August 1999 may explain why productivity at this time period was slightly higher than productivity in August 2000. Additionally, low concentrations of ortho-phosphorus stretching throughout the study period suggest that phosphorus was limiting, not only in August 2000, but throughout the duration of the study.

Similarly, the findings of the current study for Station 17 concur with Gibbs's with respect to which nutrient was limiting in the reservoir. She found a shortage of total phosphorus in the system and suggested that phosphorus was likely limiting. The determination of phosphorus as the nutrient most likely to be limiting in this reservoir, is in keeping with the widespread belief that phosphorus limits phytoplankton abundance in temperate lake systems (Wetzel, 1983). However, the fact that the algal bioassay was a level I assay (Hecky and Kilham, 1988), was conducted only once (in August 2000), and

only at two stations, limits the conclusion to be drawn from this experiment. Algal productivity can be limited by other factors at other locations or at other times of the year.

Current Trophic Status of Lake Texoma

The trophic status of each experimental station was considered separately as productivity results were also only calculated on a station-by-station basis.

Wetzel (1983) assigned a mesotrophic status to a daily mean areal productivity range of 250-1000 mg $C.m^{-2}.d^{-1}$ (Table 9), referring to approximately net productivity. Estimates of net productivity in oxygen units generated by the current study were converted to carbon units to facilitate assignment of trophic status (Table 6).

The trophic status of each station was found to be mesotrophic according to Wetzel (1983), with Station 3 approaching the range for eutrophy (>1000 mg $C.m^{-2}.d^{-1}$).

The ortho-phosphorus levels, if typical historically of the reservoir, would explain why Gibbs (1998) found that the lake was oligotrophic when she determined TSI from total phosphorus. Her TSI calculated from Secchi depth and chl-a values, however, suggested that the reservoir was primarily eutrophic with seasonal mesotrophy. Ground and Groeger (1994), used the same indicators of trophic status as Gibbs, combined with others such as surface area and mean depth and came up with a mesotrophic rating for the lake. Results of the current study agree with the mesotrophic ratings, on a station-by-station basis.

Table 8. Dissolved ortho-phosphorus (PO_4)* at each of the study stations throughout the study period.

Date	Station 03	Station 09	Station 17	Station 22
August 1999	0.07	0.05	< 0.02	0.04
	0.03	0.03	< 0.02	0.04
	0.04	0.02	< 0.02	0.05
October 1999	0.02	< 0.02	< 0.02	< 0.02
	0.02	< 0.02	< 0.02	< 0.02
	0.02	< 0.02	< 0.02	< 0.02
November 1999	< 0.02	0.02	0.02	0.02
	< 0.02	0.02	0.02	0.02
	< 0.02	0.02	0.02	0.02
January 2000	0.02	0.02	0.02	< 0.02
	0.02	0.03	0.02	< 0.02
	< 0.02	0.02	0.02	< 0.02
March 2000	0.02	0.02	0.02	< 0.02
	0.02	0.02	0.02	0.02
	0.02	< 0.02	0.02	< 0.02
April 2000	0.02	< 0.02	< 0.02	0.02
	0.02	< 0.02	< 0.02	0.02
	0.02	< 0.02	< 0.02	0.02
May A 2000	0.02	< 0.02	0.02	0.02
	0.02	< 0.02	< 0.02	0.02
	0.02	0.02	0.02	0.02
May B 2000	0.02	< 0.02	0.02	0.02
	0.02	< 0.02	< 0.02	0.02
	0.02	0.02	0.02	0.02
June A 2000	< 0.02	< 0.02	0.02	0.02
	< 0.02	< 0.02	0.02	< 0.02
	< 0.02	< 0.02	0.02	< 0.02
June B 2000	0.02	0.02	0.02	0.02
	0.02	0.02	0.02	0.02
	0.02	0.02	0.02	0.02
July 2000	< 0.02	< 0.02	< 0.02	< 0.02
	< 0.02	< 0.02	< 0.02	< 0.02
	< 0.02	< 0.02	< 0.02	< 0.02

*Three replicate samples were collected from a depth of 1m and analyzed at the EPA lab in Ada, OK. Data shown are concentration in mg/l and detection limit of the methods is 0.02 mg/l

Table 9. General ranges of primary productivity, chl-a and light extinction coefficients for lakes of different trophic categories.

Trophic Type	Mean Primary Productivity ($mgC.m^{-2}.day^{-1}$)	Chlorophyll-a ($mg.m^{-3}$)	Light Extinction Coefficients ($n\ m^{-1}$)
Oligotrophic	50-300	0.30-3	0.05-1.0
Mesotrophic	250-1000	2-15	0.1-2.0
Eutrophic	>1000	10-500	0.5-4.0
Dystrophic	<50-500	0.1-1.0	1.0-4.0

Modified from Wetzel (1983).
Mean primary productivity refers approximately to net primary productivity.

SUMMARY AND RECOMMENDATIONS

This study focused on determining the spatial and temporal variability of areal and volumetric phytoplankton productivity in Lake Texoma, using data from four stations representative of the different zones of the reservoir; on verifying what nutrient parameter most likely limited phytoplankton biomass at two of these stations, and on determining the current trophic status of the reservoir on a station-by-station basis. A summary of the findings follows:

Gross areal and volumetric productivity showed a strong seasonal pattern driven mostly by changes in light and temperature. Spatial variability among stations was driven by turbidity and algal biomass.

In August 2000, phosphorus was found to be the limiting nutrient at Station 17 (Main Lake Zone) and Station 22. Station 22 was, however, primarily light-limited. Ortho- phosphorus data for the period of the study confirmed that phosphorus was indeed in short supply in the system.

The trophic status of all stations was found to be mesotrophic although Station 3 tended towards a eutrophic rating because of its high algal biomass. This observation may have implications for future water quality management of the reservoir.

Future productivity studies based on samples from a greater number of stations representative of each zone of the reservoir, and based on samples from varying depths would provide valuable data for extrapolation to lake-wide estimates of productivity, while also solidifying any trophic-status determination. It should be borne in mind,

however, that, in the present study, variability of the areal productivity data was such that the minimum difference between the means that would enable one to observe that there were differences in areal productivities between stations was 30%.

Nutrient limitation assays conducted at regular intervals at at least one station representative of each zone, would be useful in shedding further light on nutrient dynamics of the system.

APPENDIX A

PRIMARY PRODUCTIVITY DATASHEETS

Primary Productivity Raw Data
Station 3, August 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
33	0.00	0.000	-1.12	13.183	-2.309	0.080
34	0.00	0.000	-1.16	13.200	-2.389	0.000
35	0.00	0.000	-1.16	13.233	-2.383	0.006
36	0.00	0.000	-1.16	13.250	-2.380	0.009
1	32.64	0.118	0.19	12.300	0.420	2.809
3	47.14	0.170	0.53	12.433	1.159	3.548
4	47.22	0.170	0.48	12.467	1.047	3.436
2	49.43	0.178	0.47	12.383	1.032	3.421
9	57.45	0.207	0.83	12.583	1.793	4.182
10	76.67	0.276	1.11	12.633	2.388	4.777
12	76.90	0.277	1.35	12.767	2.874	5.263
11	90.34	0.325	1.30	12.717	2.779	5.168
17	103.91	0.374	1.68	12.817	3.563	5.952
18	132.39	0.477	2.21	12.867	4.669	7.058
19	143.05	0.515	2.36	12.900	4.973	7.362
20	152.49	0.549	2.37	12.950	4.974	7.363
25	153.34	0.552	2.35	12.983	4.920	7.309
26	205.50	0.740	2.88	13.050	5.999	8.388
27	248.70	0.895	3.13	13.100	6.494	8.883
28	287.00	1.033	3.27	13.150	6.759	9.148

chlorophyll-a = 36.8 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, August 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
37	0.00	0.000	-0.760	14.467	-1.882	0.144
38	0.00	0.000	-0.820	14.500	-2.026	0.000
39	0.00	0.000	-0.820	14.517	-2.024	0.002
40	0.00	0.000	-0.800	14.550	-1.970	0.056
8	30.03	0.108	0.310	13.750	0.808	2.834
7	39.05	0.141	0.590	13.700	1.543	3.569
16	42.38	0.153	0.480	13.967	1.231	3.257
6	47.60	0.171	0.730	13.683	1.911	3.937
5	50.48	0.182	0.790	13.650	2.074	4.100
24	52.75	0.190	0.890	14.217	2.243	4.269
15	54.14	0.195	1.080	13.917	2.781	4.807
14	75.92	0.273	1.420	13.900	3.660	5.686
13	80.52	0.290	1.530	13.833	3.963	5.989
23	99.41	0.358	1.740	14.183	4.396	6.422
22	130.36	0.469	2.350	14.100	5.972	7.998
21	161.79	0.582	2.370	14.117	6.015	8.041
32	206.60	0.744	2.790	14.433	6.926	8.952
31	234.30	0.843	2.050	14.383	5.107	7.133
30	262.10	0.944	3.170	14.350	7.915	9.941
29	278.50	1.003	3.220	14.300	8.068	10.094

chlorophyll-a = 27.9 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, August 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
34	0.00	0.000	-0.510	18.297	-1.232	0.046
35	0.00	0.000	-0.530	18.330	-1.278	0.000
36	0.00	0.000	-0.490	18.363	-1.179	0.099
6	48.98	0.176	1.030	17.313	2.629	3.907
3	53.95	0.194	1.010	17.147	2.603	3.881
4	55.60	0.200	1.040	17.230	2.667	3.945
5	56.64	0.204	1.060	17.263	2.713	3.991
14	70.24	0.253	1.610	17.580	4.047	5.325
11	70.62	0.254	1.630	17.413	4.136	5.414
12	74.37	0.268	1.720	17.480	4.348	5.626
13	77.28	0.278	1.720	17.547	4.332	5.610
22	146.85	0.529	2.390	18.047	5.852	7.130
19	149.34	0.538	2.440	17.813	6.053	7.331
21	152.87	0.550	2.450	17.997	6.016	7.294
20	154.18	0.555	2.50	17.897	6.173	7.451
30	268.00	0.965	2.630	18.247	6.369	7.647
27	283.70	1.021	2.630	18.080	6.428	7.706
29	300.20	1.081	2.650	18.197	6.435	7.713
28	303.90	1.094	2.640	18.147	6.429	7.707

chlorophyll-a = 22.6 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, August 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
33	0.00	0.000	-0.520	19.26	-1.484	0.22
34	0.00	0.000	-0.540	19.28	-1.540	0.17
35	0.00	0.000	-0.600	19.30	-1.709	0.00
36	0.00	0.000	-0.600	19.31	-1.708	0.00
5	43.73	0.157	0.640	18.81	1.870	3.58
6	45.54	0.164	0.560	18.85	1.634	3.34
4	47.85	0.172	0.620	18.80	1.813	3.52
3	51.64	0.186	0.560	18.76	1.641	3.35
14	78.78	0.284	0.870	18.96	2.522	4.23
12	79.63	0.287	1.160	18.91	3.372	5.08
11	80.47	0.290	1.020	18.88	2.970	4.68
13	80.71	0.291	1.120	18.95	3.250	4.96
22	133.28	0.480	1.400	19.11	4.027	5.74
21	134.17	0.483	1.980	19.08	5.705	7.41
19	135.25	0.487	1.970	19.03	5.691	7.40
20	135.76	0.489	1.930	19.05	5.571	7.28
27	266.70	0.960	1.640	19.15	4.709	6.42
29	269.30	0.969	1.750	19.21	5.007	6.72
30	271.50	0.977	2.060	19.23	5.889	7.60
28	282.10	1.016	2.000	19.18	5.733	7.44

chlorophyll-a = 18.2 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, October 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.000	-0.45	19.43	-0.992	0.042
37	0.00	0.000	-0.44	19.45	-0.969	0.065
38	0.00	0.000	-0.47	19.47	-1.034	0.000
39	0.00	0.000	-0.39	19.48	-0.857	0.177
20	35.51	0.128	1.53	18.80	3.485	4.519
21	43.02	0.155	1.87	18.83	4.252	5.286
22	45.10	0.162	1.99	18.87	4.517	5.551
23	45.56	0.164	2.06	18.88	4.672	5.706
27	84.40	0.304	3.36	19.12	7.527	8.561
26	90.98	0.328	3.56	19.08	7.989	9.023
25	96.38	0.347	3.60	18.97	8.129	9.163
24	102.77	0.370	3.57	18.93	8.075	9.109
31	142.16	0.512	4.06	19.23	9.040	10.074
30	165.70	0.597	4.48	19.20	9.993	11.027
29	172.19	0.620	4.29	19.15	9.594	10.628
28	177.25	0.638	4.05	19.02	9.121	10.155
33	370.00	1.332	4.55	19.30	10.096	11.130
32	375.30	1.351	4.51	18.77	10.292	11.326
34	386.20	1.390	4.47	19.37	9.885	10.919
35	398.50	1.435	4.47	19.40	9.868	10.902

chlorophyll-a = 23.35 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, October 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
63	0.00	0.000	-0.45	21.32	-1.240	0.000
64	0.00	0.000	-0.44	21.33	-1.212	0.028
65	0.00	0.000	-0.43	21.37	-1.182	0.058
66	0.00	0.000	-0.37	21.40	-1.016	0.224
17	51.48	0.185	0.93	20.62	2.650	3.890
18	52.44	0.189	1.34	20.67	3.810	5.050
19	58.24	0.210	1.43	20.70	4.059	5.299
36	63.23	0.228	1.65	20.78	4.665	5.905
44	106.86	0.385	2.84	20.92	7.977	9.217
38	107.85	0.388	2.51	20.82	7.084	8.324
48	108.65	0.391	2.68	20.98	7.504	8.744
39	112.17	0.404	2.80	20.85	7.890	9.130
49	142.01	0.511	3.27	21.03	9.134	10.374
53	180.98	0.652	3.36	21.15	9.334	10.574
50	187.60	0.675	3.25	21.07	9.064	10.304
52	189.43	0.682	3.31	21.10	9.217	10.457
54	227.30	0.818	3.41	21.18	9.458	10.698
55	269.50	0.970	3.43	21.22	9.499	10.739
56	320.40	1.153	3.44	21.23	9.519	10.759
57	361.40	1.301	3.42	21.28	9.441	10.681

chlorophyll-a = 17.02 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, October 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.000	-0.38	18.70	-1.146	0.026
2	0.00	0.000	-0.38	18.72	-1.145	0.027
3	0.00	0.000	-0.37	18.75	-1.113	0.059
4	0.00	0.000	-0.39	18.77	-1.172	0.000
37	46.76	0.168	1.13	18.22	3.498	4.670
38	57.11	0.206	1.45	18.25	4.480	5.652
41	59.47	0.214	1.49	18.27	4.600	5.772
42	61.00	0.220	1.48	18.30	4.561	5.733
51	89.00	0.320	2.16	18.39	6.626	7.798
47	97.79	0.352	2.19	18.35	6.730	7.902
45	99.91	0.360	2.12	18.32	6.527	7.699
43	105.31	0.379	2.02	18.29	6.230	7.402
69	141.55	0.510	2.27	18.49	6.926	8.098
68	164.95	0.594	2.36	18.45	7.213	8.385
58	173.74	0.625	2.40	18.39	7.362	8.534
59	174.35	0.628	2.37	18.42	7.257	8.429
70	355.10	1.278	2.40	18.50	7.317	8.489
71	362.80	1.306	2.38	18.52	7.249	8.421
72	366.10	1.318	2.43	18.55	7.388	8.560
87	394.50	1.420	2.52	18.58	7.648	8.820

chlorophyll-a = 17.73 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, October 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.000	-0.55	20.50	-1.427	0.00
37	0.00	0.000	-0.52	20.53	-1.347	0.08
38	0.00	0.000	-0.39	20.57	-1.009	0.42
39	0.00	0.000	-0.48	20.60	-1.239	0.19
20	58.62	0.211	1.67	19.95	4.453	5.88
23	58.80	0.212	1.49	19.92	3.979	5.41
21	58.93	0.212	1.66	19.97	4.422	5.85
22	59.18	0.213	1.60	19.87	4.284	5.71
27	101.50	0.365	2.32	20.15	6.124	7.55
26	107.61	0.387	2.42	20.12	6.399	7.83
24	107.66	0.388	2.50	20.05	6.632	8.06
25	110.91	0.399	2.46	20.08	6.515	7.94
31	184.59	0.665	2.87	20.30	7.520	8.95
30	187.65	0.676	2.97	20.25	7.801	9.23
29	192.91	0.694	2.89	20.22	7.604	9.03
28	200.10	0.720	2.98	20.18	7.854	9.28
32	339.30	1.221	2.94	20.35	7.685	9.11
35	357.80	1.288	2.89	20.48	7.505	8.93
33	358.20	1.290	2.77	20.38	7.228	8.66
34	369.80	1.331	2.92	20.45	7.595	9.02

chlorophyll-a = 18.80 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, November 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.000	-0.8200	18.17	-2.429	0.000
37	0.00	0.000	-0.8100	18.19	-2.397	0.032
38	0.00	0.000	-0.8000	18.22	-2.363	0.066
39	0.00	0.000	-0.8000	18.24	-2.361	0.068
30	48.34	0.174	0.6300	17.67	1.919	4.348
17	48.35	0.174	0.5500	17.75	1.667	4.096
19	49.50	0.178	0.6300	17.70	1.915	4.344
18	50.39	0.181	0.5600	17.74	1.699	4.128
43	106.08	0.382	1.0400	17.85	3.135	5.564
39	109.88	0.396	1.0400	17.79	3.147	5.576
42	112.89	0.406	0.9700	17.82	2.930	5.359
41	114.34	0.412	1.1000	17.80	3.325	5.754
48	175.98	0.634	1.4100	17.99	4.219	6.648
47	190.64	0.686	1.4200	17.97	4.253	6.682
45	195.34	0.703	1.4400	17.94	4.321	6.750
44	221.60	0.798	1.4500	17.90	4.359	6.788
53	327.70	1.180	1.4900	18.14	4.422	6.851
52	347.30	1.250	1.5100	18.12	4.485	6.914
49	358.40	1.290	1.4600	18.05	4.353	6.782
50	361.20	1.300	1.3700	18.07	4.081	6.510

chlorophyll-a = 18.58 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, November 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
63	0.00	0.000	-0.27	21.14	-0.842	0.185
64	0.00	0.000	-0.26	21.17	-0.810	0.217
65	0.00	0.000	-0.33	21.19	-1.027	0.000
66	0.00	0.000	-0.30	21.20	-0.933	0.094
22	37.71	0.136	0.85	20.52	2.731	3.758
51	43.27	0.156	1.13	20.55	3.624	4.651
55	45.01	0.162	1.21	20.62	3.868	4.895
54	45.39	0.163	1.08	20.59	3.458	4.485
59	89.68	0.323	1.74	20.77	5.522	6.549
69	96.49	0.347	1.86	20.94	5.856	6.883
56	99.03	0.357	1.82	20.65	5.809	6.836
58	100.20	0.361	1.80	20.75	5.717	6.744
57	103.21	0.372	1.81	20.70	5.763	6.790
68	151.08	0.544	1.92	20.90	6.055	7.082
63	172.32	0.620	2.08	20.85	6.575	7.602
62	184.77	0.665	2.02	20.82	6.396	7.423
40	222.10	0.800	2.05	21.10	6.403	7.430
72	277.80	1.000	2.06	21.05	6.450	7.477
71	327.80	1.180	2.07	21.02	6.492	7.519
70	360.80	1.299	2.07	21.00	6.497	7.524

chlorophyll-a = 15.17 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, November 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.000	-0.77	20.02	-1.699	0.000
2	0.00	0.000	-0.74	20.06	-1.630	0.069
3	0.00	0.000	-0.77	20.07	-1.694	0.005
36	0.00	0.000	-0.73	20.09	-1.605	0.094
25	30.85	0.111	0.59	19.56	1.333	3.032
24	40.41	0.145	0.94	19.54	2.125	3.824
23	46.47	0.167	1.21	19.52	2.738	4.437
21	50.94	0.183	1.19	19.49	2.697	4.396
29	98.04	0.353	1.74	19.67	3.907	5.606
28	98.37	0.354	1.83	19.64	4.116	5.815
27	103.21	0.372	1.81	19.61	4.078	5.777
26	109.13	0.393	1.92	19.59	4.329	6.028
34	193.98	0.698	2.77	19.79	6.182	7.881
31	205.00	0.738	2.48	19.71	5.559	7.258
33	215.80	0.777	2.74	19.77	6.121	7.820
32	218.10	0.785	2.59	19.74	5.795	7.494
37	360.80	1.299	2.80	19.89	6.218	7.917
38	365.50	1.316	2.70	19.91	5.991	7.690
35	367.00	1.321	2.69	19.82	5.994	7.693
36	387.60	1.395	2.75	19.86	6.117	7.816

chlorophyll-a = 22.64 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, November 1999

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.000	-0.51	39.88	-0.699	0.000
37	0.00	0.000	-0.49	39.90	-0.671	0.028
38	0.00	0.000	-0.51	39.93	-0.698	0.001
39	0.00	0.000	-0.51	39.95	-0.698	0.001
30	46.27	0.167	0.82	18.25	2.455	3.154
17	50.35	0.181	0.76	18.17	2.286	2.985
18	50.67	0.182	0.86	18.20	2.582	3.281
19	51.83	0.187	0.89	18.22	2.670	3.369
44	96.92	0.349	1.22	18.33	3.636	4.335
41	99.64	0.359	1.21	18.27	3.620	4.319
43	102.79	0.370	1.19	18.30	3.553	4.252
47	103.07	0.371	1.20	18.37	3.570	4.269
60	152.78	0.550	1.39	18.50	4.106	4.805
52	159.78	0.575	1.42	18.47	4.202	4.901
49	166.35	0.599	1.41	18.43	4.180	4.879
48	176.17	0.634	1.40	18.40	4.158	4.857
67	323.70	1.165	1.46	18.62	4.285	4.984
61	350.07	1.260	1.42	18.55	4.183	4.882
64	359.40	1.294	1.36	18.58	3.999	4.698
65	362.00	1.303	1.44	18.60	4.231	4.930

chlorophyll-a = 18.30 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, January 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.54	18.21	-1.232	0.065
37	0.00	0.00	-0.55	18.25	-1.252	0.045
38	0.00	0.00	-0.57	18.26	-1.297	0.000
39	0.00	0.00	-0.47	18.30	-1.067	0.230
19	32.90	0.12	1.59	17.55	3.765	5.062
23	41.96	0.15	1.59	17.61	3.750	5.047
22	45.39	0.16	1.46	17.56	3.454	4.751
24	52.93	0.19	1.72	17.65	4.049	5.346
25	100.49	0.36	2.37	17.70	5.564	6.861
26	101.90	0.37	2.35	17.73	5.507	6.804
27	115.85	0.42	2.39	17.78	5.585	6.882
28	125.25	0.45	2.54	17.80	5.930	7.227
33	135.16	0.49	2.73	18.01	6.296	7.593
32	150.71	0.54	2.83	17.95	6.551	7.848
31	152.54	0.55	2.85	17.91	6.610	7.907
30	153.02	0.55	2.97	17.86	6.907	8.204
37	304.50	1.10	3.02	18.20	6.895	8.192
36	320.30	1.15	2.97	18.15	6.800	8.097
35	333.60	1.20	2.97	18.11	6.812	8.109
34	348.10	1.25	2.90	18.08	6.664	7.961

chlorophyll-a = 24.07 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, January 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
63	0.00	0.00	-0.03	16.85	-0.281	1.959
64	0.00	0.00	-0.21	16.86	-1.964	0.276
65	0.00	0.00	-0.24	16.90	-2.240	0.000
66	0.00	0.00	-0.16	16.91	-1.492	0.748
44	31.11	0.11	0.21	16.26	2.037	4.277
42	45.91	0.17	0.22	16.25	2.136	4.376
41	49.22	0.18	0.28	16.23	2.721	4.961
40	53.92	0.19	0.33	16.18	3.217	5.457
45	81.22	0.29	0.43	16.31	4.158	6.398
47	89.02	0.32	0.36	16.36	3.470	5.710
48	96.45	0.35	0.37	16.40	3.559	5.799
49	100.44	0.36	0.40	16.41	3.844	6.084
50	143.05	0.51	0.51	16.46	4.886	7.126
51	147.61	0.53	0.46	16.50	4.398	6.638
52	157.28	0.57	0.46	16.53	4.389	6.629
54	161.32	0.58	0.41	16.58	3.900	6.140
55	259.7	0.93	0.53	16.65	5.022	7.262
57	320.8	1.15	0.45	16.68	4.255	6.495
58	329.5	1.19	0.45	16.71	4.247	6.487
59	342.7	1.23	0.47	16.76	4.422	6.662

chlorophyll-a = 6.34 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, January 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis ($mg\ O_2.mg\ Chl^{-1}.h^{-1}$)	Gross photosynthesis ($mg\ O_2.mg\ Chl^{-1}.h^{-1}$)
63	0.00	0.00	-0.12	18.40	-1.238	0.305
65	0.00	0.00	-0.14	18.42	-1.442	0.101
66	0.00	0.00	-0.15	18.45	-1.543	0.000
39	0.00	0.00	-0.13	18.50	-1.333	0.210
28	48.79	0.18	0.41	17.85	4.358	5.901
27	53.92	0.19	0.39	17.77	4.165	5.708
26	56.04	0.20	0.41	17.70	4.395	5.938
24	60.04	0.22	0.44	17.67	4.726	6.269
30	89.07	0.32	0.55	17.90	5.830	7.373
31	91.47	0.33	0.55	17.93	5.820	7.363
33	93.77	0.34	0.57	18.02	6.003	7.546
32	95.46	0.34	0.58	17.97	6.126	7.669
37	150.14	0.54	0.67	18.18	6.992	8.535
36	155.92	0.56	0.65	18.15	6.796	8.339
34	156.53	0.56	0.63	18.07	6.617	8.160
35	157.71	0.57	0.64	18.12	6.703	8.246
38	319.30	1.15	0.67	18.25	6.966	8.509
39	341.80	1.23	0.64	18.30	6.636	8.179
41	342.80	1.23	0.63	18.35	6.515	8.058
40	351.40	1.27	0.72	18.32	7.459	9.002

chlorophyll-a = 5.27 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, January 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis ($mg\ O_2.mg\ Chl^{-1}.h^{-1}$)	Gross photosynthesis ($mg\ O_2.mg\ Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.03	18.07	-0.194	0.000
38	0.00	0.00	0.02	18.10	0.129	0.323
64	0.00	0.00	0.12	18.12	0.776	0.970
66	0.00	0.00	0.00	18.15	0.000	0.194
34	46.86	0.17	0.76	17.32	5.139	5.333
32	48.99	0.18	0.79	17.27	5.357	5.551
33	51.21	0.18	0.74	17.35	4.994	5.188
35	52.81	0.19	0.73	17.33	4.932	5.126
40	81.22	0.29	1.18	17.40	7.941	8.135
41	91.14	0.33	1.08	17.43	7.254	7.448
44	96.35	0.35	1.08	17.50	7.226	7.420
42	101.90	0.37	1.14	17.55	7.606	7.800
58	171.61	0.62	1.18	17.65	7.829	8.023
57	176.69	0.64	1.19	17.88	7.792	7.986
55	182.18	0.66	1.19	17.83	7.814	8.008
59	184.30	0.66	1.18	17.80	7.763	7.957
50	277.00	1.00	1.21	17.92	7.908	8.102
53	304.90	1.10	1.23	17.97	8.016	8.210
52	333.30	1.20	1.20	18.00	7.806	8.000
51	338.90	1.22	1.28	18.03	8.311	8.505

chlorophyll-a = 8.54 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, March 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.000	-0.470	17.380	-2.549	0.000
37	0.00	0.000	-0.460	17.413	-2.490	0.059
38	0.00	0.000	-0.470	17.430	-2.541	0.008
39	0.00	0.000	-0.470	17.447	-2.539	0.010
17	43.59	0.157	0.670	16.697	3.782	6.331
18	44.02	0.158	0.850	16.730	4.789	7.338
21	45.35	0.163	0.850	16.797	4.770	7.319
19	46.96	0.169	0.810	16.763	4.554	7.103
25	75.67	0.272	1.250	16.997	6.932	9.481
24	80.99	0.292	1.320	16.963	7.334	9.883
23	90.29	0.325	1.370	16.930	7.627	10.176
22	91.23	0.328	1.340	16.880	7.482	10.031
30	117.73	0.424	1.590	17.180	8.723	11.272
28	138.26	0.498	1.620	17.147	8.905	11.454
27	144.37	0.520	1.630	17.113	8.977	11.526
26	154.04	0.555	1.530	17.063	8.451	11.000
35	272.80	0.982	1.690	17.347	9.182	11.731
34	275.00	0.990	1.600	17.297	8.719	11.268
33	312.60	1.125	1.680	17.263	9.172	11.721
31	321.40	1.157	1.720	17.230	9.409	11.958

chlorophyll-a = 10.61 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, March 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.43	16.637	-7.406	0.000
63	0.00	0.00	-0.39	16.670	-6.704	0.702
65	0.00	0.00	-0.38	16.703	-6.519	0.887
4	0.00	0.00	-0.40	16.737	-6.848	0.558
39	31.30	0.11	-0.03	16.187	-0.531	6.875
38	37.03	0.13	0.05	16.170	0.886	8.292
37	44.33	0.16	0.11	16.137	1.953	9.359
36	51.55	0.19	0.19	16.120	3.377	10.783
43	90.15	0.32	0.41	16.320	7.198	14.604
42	91.28	0.33	0.34	16.287	5.982	13.388
41	101.57	0.37	0.40	16.253	7.052	14.458
40	105.32	0.38	0.50	16.220	8.833	16.239
44	137.65	0.50	0.54	16.353	9.462	16.868
48	149.16	0.54	0.49	16.437	8.542	15.948
45	151.79	0.55	0.56	16.387	9.792	17.198
47	152.16	0.55	0.57	16.420	9.947	17.353
49	262.80	0.95	0.63	16.470	10.960	18.366
50	297.80	1.07	0.59	16.503	10.244	17.650
51	303.30	1.09	0.65	16.570	11.240	18.646
52	318.10	1.15	0.53	16.620	9.137	16.543

chlorophyll-a = 3.49 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, March 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.090	18.290	-2.227	2.222
3	0.00	0.00	-0.180	18.307	-4.449	0.000
64	0.00	0.00	-0.130	18.340	-3.207	1.242
66	0.00	0.00	-0.150	18.357	-3.697	0.752
29	32.83	0.12	0.150	17.773	3.819	8.268
31	45.40	0.16	0.200	17.790	5.087	9.536
42	46.13	0.17	0.260	17.807	6.607	11.056
43	50.11	0.18	0.290	17.840	7.355	11.804
53	90.81	0.33	0.450	17.907	11.371	15.820
55	91.79	0.33	0.470	17.923	11.866	16.315
47	92.03	0.33	0.460	17.873	11.646	16.095
57	102.88	0.37	0.480	17.957	12.095	16.544
70	138.12	0.50	0.560	18.107	13.994	18.443
59	143.66	0.52	0.540	18.040	13.545	17.994
58	153.48	0.55	0.550	*18.007*	13.821	18.270
69	153.76	0.55	0.530	18.073	13.269	17.718
114	340.70	1.23	0.590	18.207	14.663	19.112
71	342.00	1.23	0.570	18.140	14.218	18.667
100	343.00	1.23	0.520	18.157	12.959	17.408
142	354.90	1.28	0.580	18.240	14.388	18.837

chlorophyll-a = 2.21 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, March 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.260	18.053	-2.063	0.000
37	0.00	0.00	-0.260	18.070	-2.061	0.002
38	0.00	0.00	-0.230	18.087	-1.822	0.241
39	0.00	0.00	-0.240	18.120	-1.898	0.165
21	32.63	0.12	0.500	17.687	4.050	6.113
19	40.38	0.15	0.630	17.653	5.113	7.176
18	45.43	0.16	0.640	17.620	5.204	7.267
17	51.64	0.19	0.620	17.587	5.051	7.114
22	86.20	0.31	0.850	17.720	6.872	8.935
24	90.01	0.32	1.030	17.770	8.304	10.367
23	90.48	0.33	0.880	17.737	7.108	9.171
25	97.48	0.35	1.140	17.820	9.165	11.228
26	130.08	0.47	1.210	17.837	9.719	11.782
27	153.71	0.55	1.390	17.870	11.144	13.207
30	156.77	0.56	1.420	*17.920*	11.353	13.416
28	162.31	0.58	1.440	17.887	11.534	13.597
31	226.10	0.81	1.520	17.953	12.130	14.193
33	249.80	0.90	1.540	17.970	12.278	14.341
34	296.10	1.07	1.620	18.003	12.892	14.955
35	334.70	1.20	1.560	18.020	12.403	14.466

chlorophyll-a = 6.98 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, April 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.390	16.42	-2.144	0.000
2	0.00	0.00	-0.380	16.44	-2.087	0.057
3	0.00	0.00	-0.380	16.47	-2.082	0.062
4	0.00	0.00	-0.370	16.50	-2.023	0.121
33	30.49	0.11	0.560	16.02	3.155	5.299
32	33.48	0.12	0.860	15.99	4.855	6.999
31	42.50	0.15	1.000	15.97	5.651	7.795
30	44.57	0.16	1.160	15.94	6.569	8.713
37	93.49	0.34	2.090	16.15	11.677	13.821
36	96.65	0.35	2.090	16.12	11.701	13.845
35	106.59	0.38	2.250	16.09	12.623	14.767
34	110.49	0.40	2.160	16.05	12.144	14.288
38	138.26	0.50	2.590	16.19	14.441	16.585
39	154.84	0.56	2.930	16.24	16.287	18.431
40	163.53	0.59	2.970	16.27	16.475	18.619
41	166.02	0.60	2.940	16.29	16.292	18.436
42	307.30	1.11	3.490	16.32	19.300	21.444
45	336.90	1.21	3.460	16.37	19.076	21.220
47	340.20	1.22	3.450	16.39	19.002	21.146
43	350.90	1.26	3.380	16.34	18.673	20.817

chlorophyll-a = 11.08 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, April 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.55	16.57	-3.655	0.000
37	0.00	0.00	-0.53	16.61	-3.515	0.140
38	0.00	0.00	-0.52	16.62	-3.445	0.210
39	0.00	0.00	-0.49	16.66	-3.240	0.415
17	34.65	0.12	0.64	16.06	4.390	8.045
18	45.90	0.17	0.93	16.07	6.372	10.027
21	47.43	0.17	1.15	16.14	7.847	11.502
19	47.73	0.17	1.08	16.11	7.385	11.040
25	53.79	0.19	1.42	16.31	9.590	13.245
24	70.33	0.25	1.70	16.27	11.505	15.160
23	88.46	0.32	1.86	16.24	12.614	16.269
22	92.92	0.33	1.79	16.19	12.176	15.831
48	147.19	0.53	2.41	16.44	16.145	19.800
27	161.56	0.58	2.57	16.37	17.287	20.942
26	163.20	0.59	2.58	16.34	17.389	21.044
28	165.60	0.60	2.61	16.41	17.520	21.175
52	268.50	0.97	2.71	16.56	18.026	21.681
51	272.10	0.98	2.74	16.52	18.263	21.918
50	320.80	1.15	2.74	16.49	18.300	21.955
49	345.00	1.24	2.83	16.47	18.920	22.575

chlorophyll-a = 9.08 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, April 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.13	16.95	-1.581	0.120
2	0.00	0.00	-0.14	16.97	-1.701	0.000
3	0.00	0.00	-0.14	17.00	-1.698	0.003
4	0.00	0.00	-0.12	17.02	-1.454	0.247
33	43.71	0.16	0.51	16.40	6.412	8.113
32	45.04	0.16	0.57	16.38	7.174	8.875
31	49.09	0.18	0.62	16.33	7.827	9.528
30	49.84	0.18	0.61	16.32	7.708	9.409
37	92.08	0.33	0.99	16.68	12.235	13.936
35	97.48	0.35	1.08	16.47	13.523	15.224
36	98.28	0.35	1.08	16.67	13.361	15.062
34	102.13	0.37	1.07	16.45	13.412	15.113
38	157.52	0.57	1.59	16.73	19.592	21.293
40	159.59	0.57	1.67	16.75	20.557	22.258
41	162.69	0.59	1.62	16.78	19.902	21.603
42	163.30	0.59	1.66	16.82	20.353	22.054
47	314.30	1.13	1.82	16.93	22.161	23.862
45	346.30	1.25	1.82	16.92	22.183	23.884
44	351.60	1.27	1.83	16.88	22.349	24.050
43	354.00	1.27	1.88	16.85	23.005	24.706

chlorophyll-a = 4.85 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, April 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.37	16.48	-4.757	0.247
37	0.00	0.00	-0.39	16.51	-5.004	0.000
38	0.00	0.00	-0.33	16.53	-4.230	0.774
39	0.00	0.00	-0.37	16.55	-4.737	0.267
24	32.41	0.12	0.09	16.01	1.191	6.195
23	38.74	0.14	0.27	16.00	3.576	8.580
19	44.21	0.16	0.36	15.96	4.778	9.782
18	47.23	0.17	0.31	15.91	4.127	9.131
48	90.34	0.33	0.68	16.20	8.895	13.899
39	94.94	0.34	0.70	16.18	9.166	14.170
26	113.97	0.41	0.94	16.13	12.347	17.351
25	124.07	0.45	0.93	16.10	12.241	17.245
49	150.33	0.54	0.99	16.21	12.937	17.941
51	157.57	0.57	1.19	16.26	15.502	20.506
53	160.25	0.58	1.16	16.30	15.081	20.085
54	160.76	0.58	1.01	16.31	13.117	18.121
59	348.10	1.25	1.34	16.45	17.262	22.266
58	354.80	1.28	1.29	16.43	16.635	21.639
57	385.40	1.39	1.35	16.40	17.444	22.448
55	391.10	1.41	1.32	16.38	17.073	22.077

chlorophyll-a = 4.72 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, May A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.420	16.87	-2.567	0.119
2	0.00	0.00	-0.440	16.89	-2.686	0.000
3	0.00	0.00	-0.370	16.92	-2.254	0.432
4	0.00	0.00	-0.410	16.95	-2.493	0.193
17	32.20	0.12	0.710	16.19	4.522	7.208
18	41.38	0.15	1.270	16.22	8.072	10.758
19	45.68	0.16	1.480	16.24	9.397	12.083
21	47.70	0.17	1.600	16.27	10.138	12.824
25	67.25	0.24	2.470	16.47	15.461	18.147
24	83.25	0.30	2.550	16.44	15.994	18.680
23	95.77	0.34	2.870	16.40	18.038	20.724
22	96.35	0.35	3.040	16.37	19.145	21.831
30	159.30	0.57	4.660	16.65	28.848	31.534
26	166.45	0.60	4.940	16.54	30.797	33.483
27	168.93	0.61	5.500	16.60	34.150	36.836
28	173.50	0.62	5.490	16.64	34.020	36.706
35	269.10	0.97	5.620	16.84	34.412	37.098
34	303.30	1.09	5.850	16.80	35.891	38.577
33	333.90	1.20	5.930	16.75	36.491	39.177
31	361.10	1.30	6.240	16.72	38.475	41.161

chlorophyll-a = 9.70 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, May A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.26	16.95	-3.478	0.127
37	0.00	0.00	-0.26	16.97	-3.475	0.130
38	0.00	0.00	-0.27	16.98	-3.605	0.000
39	0.00	0.00	-0.26	17.00	-3.468	0.137
40	35.14	0.13	0.37	16.55	5.070	8.675
39	45.21	0.16	0.54	16.53	7.406	11.011
38	50.33	0.18	0.59	16.48	8.116	11.721
36	50.76	0.18	0.61	16.45	8.409	12.014
48	95.93	0.35	1.44	16.67	19.592	23.197
47	102.18	0.37	1.33	16.63	18.132	21.737
45	113.03	0.41	1.38	16.62	18.832	22.437
44	117.16	0.42	1.42	16.58	19.417	23.022
49	127.59	0.46	2.09	16.70	28.379	31.984
50	159.40	0.57	2.25	16.73	30.490	34.095
51	164.47	0.59	2.38	16.78	32.156	35.761
52	165.18	0.59	2.48	16.83	33.407	37.012
53	329.10	1.18	2.98	16.85	40.103	43.708
58	346.50	1.25	3.00	16.93	40.174	43.779
57	348.50	1.25	2.92	16.90	39.179	42.784
55	356.70	1.28	3.12	16.88	41.904	45.509

chlorophyll-a = 4.41 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, May A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.32	18.50	-5.474	0.000
37	0.00	0.00	-0.31	18.52	-5.298	0.176
38	0.00	0.00	-0.32	18.53	-5.464	0.010
39	0.00	0.00	-0.32	18.55	-5.459	0.015
39	32.88	0.12	0.32	18.15	5.579	11.053
38	40.16	0.14	0.56	18.12	9.782	15.256
36	47.37	0.17	0.68	18.10	11.889	17.363
32	51.00	0.18	0.75	18.07	13.137	18.611
40	97.48	0.35	1.44	18.18	25.061	30.535
47	98.65	0.36	1.32	18.25	22.889	28.363
45	100.67	0.36	1.34	18.23	23.257	28.731
44	109.13	0.39	1.49	18.20	25.908	31.382
48	118.20	0.43	1.55	18.28	26.828	32.302
49	150.19	0.54	1.78	18.30	30.781	36.255
51	168.46	0.61	1.97	18.37	33.943	39.417
50	169.97	0.61	1.91	18.33	32.969	38.443
52	279.20	1.01	2.3	18.40	39.557	45.031
53	308.50	1.11	2.28	18.42	39.178	44.652
55	322.60	1.16	2.31	18.45	39.621	45.095
57	349.90	1.26	2.29	18.47	39.243	44.717

chlorophyll-a = 3.16 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, May A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.35	18.92	-8.010	0.221
2	0.00	0.00	-0.36	18.93	-8.231	0.000
3	0.00	0.00	-0.35	18.95	-7.996	0.235
4	0.00	0.00	-0.36	18.97	-8.217	0.014
17	31.66	0.11	-0.09	18.25	-2.135	6.096
18	37.82	0.14	0.04	18.28	0.947	9.178
19	43.54	0.16	0.12	18.32	2.836	11.067
21	48.61	0.17	0.08	18.35	1.887	10.118
25	82.87	0.30	0.22	18.50	5.148	13.379
24	86.39	0.31	0.30	18.53	7.007	15.238
23	91.61	0.33	0.40	18.58	9.318	17.549
22	93.67	0.34	0.36	18.60	8.379	16.610
30	163.39	0.59	0.78	18.67	18.089	26.320
26	172.32	0.62	0.80	18.77	18.454	26.685
27	185.94	0.67	0.82	18.72	18.966	27.197
28	188.59	0.68	0.86	18.68	19.927	28.158
35	298.40	1.07	1.11	18.80	25.560	33.791
34	342.00	1.23	1.13	18.83	25.974	34.205
33	347.60	1.25	1.20	18.85	27.559	35.790
31	364.10	1.31	1.18	18.88	27.052	35.283

chlorophyll-a = 2.31 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, May B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.750	18.17	-3.596	0.092
2	0.00	0.00	-0.770	18.19	-3.688	0.000
3	0.00	0.00	-0.680	18.22	-3.251	0.437
4	0.00	0.00	-0.700	18.24	-3.344	0.344
17	34.36	0.12	0.450	17.32	2.263	5.951
18	41.81	0.15	0.770	17.40	3.854	7.542
19	43.30	0.16	0.890	17.44	4.446	8.134
21	46.77	0.17	0.910	17.52	4.524	8.212
25	70.35	0.25	1.270	17.79	6.220	9.908
24	83.48	0.30	1.510	17.74	7.416	11.104
23	97.53	0.35	1.760	17.70	8.660	12.348
22	102.27	0.37	1.810	17.67	8.923	12.611
30	163.44	0.59	2.180	17.99	10.558	14.246
26	179.18	0.65	2.280	17.84	11.135	14.823
27	185.85	0.67	2.260	17.89	11.006	14.694
28	187.45	0.67	2.250	17.95	10.917	14.605
34	293.30	1.06	2.340	18.14	11.239	14.927
33	303.30	1.09	2.380	18.10	11.452	15.140
32	332.50	1.20	2.410	18.05	11.628	15.316
31	348.90	1.26	2.390	18.04	11.542	15.230

chlorophyll-a = 11.48 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, May B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.62	17.98	-7.661	0.015
37	0.00	0.00	-0.61	18.00	-7.531	0.145
38	0.00	0.00	-0.62	17.95	-7.676	0.000
39	0.00	0.00	-0.57	17.97	-7.050	0.626
39	36.93	0.13	0.09	17.62	1.135	8.811
38	41.74	0.15	0.31	17.55	3.925	11.601
36	47.75	0.17	0.43	17.52	5.455	13.131
35	52.35	0.19	0.50	17.50	6.349	14.025
43	101.47	0.37	1.14	17.62	14.380	22.056
42	103.96	0.37	1.12	17.65	14.101	21.777
41	114.63	0.41	1.29	17.67	16.226	23.902
40	118.10	0.43	1.33	17.70	16.698	24.374
44	130.88	0.47	1.40	17.82	17.462	25.138
45	157.33	0.57	1.68	17.80	20.974	28.650
47	168.65	0.61	1.65	17.78	20.619	28.295
48	176.83	0.64	1.75	17.75	21.909	29.585
49	276.80	1.00	1.70	17.92	21.085	28.761
50	319.50	1.15	1.79	17.90	22.222	29.898
51	331.30	1.19	1.80	17.88	22.367	30.043
53	341.60	1.23	1.76	17.85	21.911	29.587

chlorophyll-a = 4.50 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, May B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.19	18.65	-3.746	2.153
37	0.00	0.00	-0.30	18.70	-5.899	0.000
38	0.00	0.00	-0.29	18.63	-5.723	0.176
39	0.00	0.00	-0.29	18.68	-5.708	0.191
39	38.92	0.14	0.13	18.28	2.615	8.514
38	49.39	0.18	0.27	18.25	5.440	11.339
36	53.31	0.19	0.19	18.23	3.832	9.731
35	53.46	0.19	0.29	18.20	5.859	11.758
43	95.50	0.34	0.57	18.36	11.412	17.311
42	101.42	0.37	0.67	18.35	13.426	19.325
41	107.44	0.39	0.61	18.31	12.246	18.145
40	116.48	0.42	0.83	18.30	16.678	22.577
44	138.73	0.50	0.93	18.41	18.569	24.468
45	154.23	0.56	1.08	18.43	21.544	27.443
47	160.62	0.58	1.17	18.45	23.318	29.217
48	166.96	0.60	1.04	18.48	20.690	26.589
49	292.10	1.05	1.30	18.51	25.816	31.715
50	323.60	1.16	1.35	18.53	26.785	32.684
51	327.40	1.18	1.30	18.55	25.770	31.669
53	341.50	1.23	1.15	18.56	22.776	28.675

chlorophyll-a = 2.72 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, May B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.47	18.73	-3.016	0.250
2	0.00	0.00	-0.44	18.75	-2.821	0.445
3	0.00	0.00	-0.51	18.77	-3.266	0.000
4	0.00	0.00	-0.51	18.78	-3.263	0.003
17	29.86	0.11	0.03	18.15	0.199	3.465
18	39.31	0.14	0.26	18.18	1.719	4.985
19	44.61	0.16	0.50	18.20	3.302	6.568
21	45.97	0.17	0.55	18.23	3.626	6.892
25	82.35	0.30	1.11	18.43	7.238	10.504
24	84.61	0.30	1.28	18.40	8.361	11.627
23	91.61	0.33	1.37	18.35	8.973	12.239
22	98.23	0.35	1.36	18.32	8.924	12.190
30	155.17	0.56	1.96	18.55	12.700	15.966
26	176.12	0.63	1.90	18.47	12.366	15.632
27	178.38	0.64	1.96	18.48	12.745	16.011
28	182.23	0.66	2.05	18.52	13.307	16.573
34	287.90	1.04	2.15	18.68	13.831	17.097
33	302.40	1.09	2.12	18.67	13.650	16.916
32	315.30	1.14	2.16	18.63	13.933	17.199
31	346.60	1.25	2.15	18.60	13.893	17.159

chlorophyll-a = 8.32 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, June A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.310	19.10	-1.696	0.050
2	0.00	0.00	-0.320	19.15	-1.746	0.000
3	0.00	0.00	-0.320	19.18	-1.743	0.003
4	0.00	0.00	-0.310	19.21	-1.686	0.060
17	30.78	0.11	0.700	18.45	3.965	5.711
18	39.46	0.14	1.070	18.48	6.050	7.796
19	45.70	0.16	1.220	18.51	6.886	8.632
21	46.75	0.17	1.310	18.55	7.381	9.127
30	90.62	0.33	2.450	18.90	13.548	15.294
28	99.64	0.36	2.680	18.86	14.846	16.592
26	102.97	0.37	2.750	18.81	15.274	17.020
27	105.75	0.38	2.680	18.85	14.859	16.605
25	129.94	0.47	2.860	18.75	15.942	17.688
24	144.03	0.52	3.190	18.68	17.844	19.590
23	153.85	0.55	3.210	18.63	18.004	19.750
22	162.12	0.58	3.270	18.60	18.374	20.120
34	288.60	1.04	3.690	19.08	20.209	21.955
33	304.10	1.09	3.770	19.03	20.701	22.447
32	330.80	1.19	3.840	19.00	21.122	22.868
31	344.70	1.24	3.790	18.95	20.902	22.648

chlorophyll-a = 9.57 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, June A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.37	18.76	-2.185	0.000
37	0.00	0.00	-0.35	18.79	-2.063	0.122
38	0.00	0.00	-0.35	18.81	-2.061	0.124
39	0.00	0.00	-0.23	18.84	-1.352	0.833
39	30.77	0.11	0.75	18.37	4.520	6.705
38	38.97	0.14	1.00	18.36	6.033	8.218
36	44.39	0.16	1.16	18.32	7.011	9.196
35	48.35	0.17	1.10	18.31	6.654	8.839
48	100.67	0.36	2.24	18.62	13.320	15.505
47	102.46	0.37	2.25	18.59	13.403	15.588
45	104.01	0.37	2.06	18.57	12.283	14.468
44	107.72	0.39	2.03	18.54	12.125	14.310
40	152.68	0.55	2.53	18.42	15.208	17.393
43	164.14	0.59	2.86	18.51	17.114	19.299
41	168.23	0.61	2.62	18.46	15.720	17.905
42	168.84	0.61	2.62	18.49	15.692	17.877
49	272.00	0.98	2.56	18.64	15.209	17.394
50	306.50	1.10	2.81	18.67	16.665	18.850
51	321.70	1.16	2.98	18.71	17.641	19.826
53	337.30	1.21	2.81	18.72	16.620	18.805

chlorophyll-a = 9.03 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, June A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.80	18.52	-6.344	0.000
2	0.00	0.00	-0.78	18.53	-6.180	0.164
3	0.00	0.00	-0.73	18.55	-5.779	0.565
4	0.00	0.00	-0.76	18.58	-6.005	0.339
17	34.40	0.12	0.30	17.97	2.452	8.796
18	41.93	0.15	0.58	17.98	4.736	11.080
19	44.27	0.16	0.65	18.02	5.298	11.642
21	45.89	0.17	0.75	18.05	6.102	12.446
23	97.67	0.35	1.64	18.13	13.281	19.625
22	100.58	0.36	1.65	18.10	13.386	19.730
25	103.96	0.37	1.85	18.18	14.940	21.284
24	104.24	0.38	1.75	18.17	14.145	20.489
30	172.27	0.62	1.90	18.32	15.232	21.576
26	178.10	0.64	2.32	18.23	18.684	25.028
27	182.23	0.66	2.09	18.27	16.801	23.145
28	191.30	0.69	2.20	18.28	17.669	24.013
34	316.00	1.14	2.28	18.48	18.114	24.458
33	340.10	1.22	2.34	18.45	18.624	24.968
32	347.90	1.25	2.15	18.42	17.143	23.487
31	355.60	1.28	2.33	18.38	18.612	24.956

chlorophyll-a = 6.81 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, June A 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.57	18.41	-2.035	0.000
37	0.00	0.00	-0.41	18.46	-1.460	0.575
38	0.00	0.00	-0.42	18.49	-1.492	0.543
39	0.00	0.00	-0.46	18.51	-1.633	0.402
39	32.12	0.12	0.84	17.94	3.076	5.111
38	40.19	0.14	1.18	17.92	4.326	6.361
36	43.31	0.16	1.42	17.89	5.215	7.250
35	46.14	0.17	1.54	17.87	5.661	7.696
40	86.96	0.31	3.09	18.01	11.275	13.310
41	89.26	0.32	3.32	18.02	12.103	14.138
43	96.63	0.35	3.67	18.09	13.329	15.364
42	97.95	0.35	3.65	18.06	13.281	15.316
44	136.94	0.49	4.38	18.12	15.879	17.914
45	156.67	0.56	4.57	18.16	16.537	18.572
47	167.25	0.60	4.75	18.19	17.157	19.192
48	167.90	0.60	4.72	18.22	17.018	19.053
49	242.30	0.87	5.15	18.26	18.534	20.569
50	276.90	1.00	5.20	18.29	18.680	20.715
51	323.40	1.16	5.22	18.34	18.701	20.736
53	348.30	1.25	5.26	18.37	18.810	20.845

chlorophyll-a = 15.22 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, June B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.570	17.44	-2.174	0.450
2	0.00	0.00	-0.670	17.47	-2.550	0.074
3	0.00	0.00	-0.690	17.49	-2.624	0.000
4	0.00	0.00	-0.620	17.52	-2.353	0.271
17	36.19	0.13	0.930	16.80	3.680	6.304
19	42.99	0.15	1.430	16.89	5.630	8.254
18	44.43	0.16	1.290	16.85	5.089	7.713
21	49.00	0.18	1.530	16.94	6.006	8.630
26	57.85	0.21	1.660	17.09	6.460	9.084
24	80.19	0.29	2.440	17.05	9.513	12.137
23	93.06	0.34	2.610	17.02	10.196	12.820
22	103.26	0.37	2.710	16.97	10.618	13.242
31	157.10	0.57	4.050	17.22	15.638	18.262
28	171.61	0.62	4.150	17.15	16.086	18.710
30	172.23	0.62	3.960	17.19	15.320	17.944
27	177.86	0.64	4.220	17.14	16.373	18.997
35	307.40	1.11	4.320	17.42	16.489	19.113
34	315.60	1.14	4.640	17.35	17.778	20.402
33	337.40	1.21	4.550	17.32	17.467	20.091
32	342.20	1.23	4.560	17.29	17.539	20.163

chlorophyll-a = 15.04 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, June B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.65	17.42	-2.480	0.036
37	0.00	0.00	-0.66	17.44	-2.516	0.000
38	0.00	0.00	-0.65	17.46	-2.476	0.040
39	0.00	0.00	-0.66	17.49	-2.509	0.007
40	31.02	0.11	0.57	16.72	2.266	4.782
39	37.99	0.14	0.90	16.71	3.582	6.098
38	46.35	0.17	1.00	16.64	3.996	6.512
36	50.66	0.18	0.95	16.61	3.804	6.320
44	102.13	0.37	2.04	16.94	8.007	10.523
43	107.16	0.39	2.19	16.82	8.655	11.171
42	120.36	0.43	2.58	16.81	10.207	12.723
41	130.41	0.47	2.63	16.77	10.425	12.941
45	151.46	0.55	2.70	17.02	10.546	13.062
49	171.71	0.62	2.58	17.17	9.989	12.505
47	177.86	0.64	2.76	17.11	10.727	13.243
48	183.36	0.66	2.66	17.14	10.319	12.835
50	322.10	1.16	2.90	17.26	11.174	13.690
52	336.00	1.21	2.81	17.34	10.775	13.291
51	344.30	1.24	2.77	17.31	10.642	13.158
53	344.30	1.24	2.74	17.37	10.486	13.002

chlorophyll-a = 15.04 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, June B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.29	17.12	-4.277	0.728
37	0.00	0.00	-0.34	17.15	-5.005	0.000
38	0.00	0.00	-0.30	17.20	-4.403	0.602
39	0.00	0.00	-0.29	17.22	-4.252	0.753
40	30.39	0.11	0.09	16.68	1.362	6.367
39	37.73	0.14	0.21	16.65	3.184	8.189
38	41.34	0.15	0.25	16.62	3.798	8.803
36	44.56	0.16	0.34	16.58	5.176	10.181
44	83.48	0.30	0.83	16.80	12.473	17.478
43	88.60	0.32	0.80	16.77	12.046	17.051
42	91.84	0.33	0.81	16.73	12.221	17.226
41	96.87	0.35	0.79	16.72	11.931	16.936
45	155.83	0.56	1.24	16.85	18.579	23.584
47	168.89	0.61	1.41	16.87	21.105	26.110
48	171.14	0.62	1.34	16.90	20.018	25.023
49	173.50	0.62	1.34	16.92	19.998	25.003
50	244.20	0.88	1.50	16.95	22.342	27.347
51	286.20	1.03	1.42	17.00	21.088	26.093
52	308.60	1.11	1.47	17.03	21.788	26.793
53	336.30	1.21	1.46	17.08	21.576	26.581

chlorophyll-a = 3.96 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, June B 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.47	16.68	-2.176	0.088
2	0.00	0.00	-0.49	16.71	-2.264	0.000
3	0.00	0.00	-0.45	16.73	-2.077	0.187
4	0.00	0.00	-0.48	16.75	-2.213	0.051
17	36.97	0.13	0.54	16.05	2.599	4.863
18	42.02	0.15	0.89	16.08	4.274	6.538
21	42.04	0.15	1.03	16.15	4.926	7.190
19	43.60	0.16	1.00	16.11	4.792	7.056
22	97.15	0.35	1.96	16.23	9.325	11.589
23	98.23	0.35	1.95	16.25	9.268	11.532
24	99.26	0.36	2.06	16.30	9.761	12.025
26	101.00	0.36	2.09	16.33	9.883	12.147
31	156.67	0.56	2.64	16.48	12.370	14.634
30	174.25	0.63	2.79	16.45	13.100	15.364
27	175.46	0.63	2.87	16.38	13.530	15.794
28	178.28	0.64	2.79	16.43	13.113	15.377
35	321.10	1.16	2.95	16.63	13.698	15.962
33	324.90	1.17	3.07	16.56	14.313	16.577
34	326.30	1.17	2.99	16.60	13.912	16.176
32	340.20	1.22	3.02	16.51	14.122	16.386

chlorophyll-a = 12.95 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, July 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.620	17.50	-3.210	0.876
37	0.00	0.00	-0.620	17.47	-3.216	0.870
38	0.00	0.00	-0.670	17.55	-3.459	0.627
39	0.00	0.00	-0.790	17.52	-4.086	0.000
17	29.81	0.11	0.080	16.70	0.434	4.520
18	37.63	0.14	0.410	16.75	2.218	6.304
19	43.42	0.16	0.690	16.79	3.725	7.811
21	46.75	0.17	0.760	16.84	4.090	8.176
26	83.20	0.30	1.540	17.04	8.191	12.277
23	86.20	0.31	1.660	16.97	8.864	12.950
24	88.32	0.32	1.690	16.99	9.015	13.101
22	93.06	0.34	1.790	16.90	9.596	13.682
31	160.34	0.58	2.750	17.24	14.457	18.543
28	177.53	0.64	2.880	17.10	15.258	19.344
27	177.91	0.64	2.220	17.05	11.796	15.882
30	185.28	0.67	2.400	17.15	12.678	16.764
32	341.50	1.23	3.350	17.34	17.509	21.595
33	342.80	1.23	3.290	17.29	17.245	21.331
34	386.90	1.39	3.410	17.39	17.772	21.858
36	400.50	1.44	3.470	17.42	18.050	22.136

chlorophyll-a = 11.04 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, July 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.79	18.37	-6.852	0.000
2	0.00	0.00	-0.73	18.42	-6.315	0.537
3	0.00	0.00	-0.75	18.44	-6.482	0.370
4	0.00	0.00	-0.66	18.49	-5.688	1.164
41	31.84	0.11	0.41	17.67	3.697	10.549
40	42.96	0.15	0.62	17.64	5.601	12.453
39	46.74	0.17	0.67	17.59	6.070	12.922
38	50.28	0.18	0.72	17.56	6.535	13.387
42	79.91	0.29	1.38	17.71	12.420	19.272
43	89.07	0.32	1.43	17.74	12.846	19.698
45	91.89	0.33	1.53	17.79	13.706	20.558
44	95.22	0.34	1.49	17.77	13.360	20.212
48	150.24	0.54	1.91	17.84	17.062	23.914
51	164.38	0.59	2.31	17.94	20.520	27.372
49	170.16	0.61	2.18	17.89	19.419	26.271
50	171.14	0.62	2.19	17.91	19.490	26.342
52	175.46	0.63	2.28	18.16	20.012	26.864
53	238.80	0.86	2.55	18.19	22.341	29.193
54	294.40	1.06	3.04	18.27	26.512	33.364
55	323.50	1.16	2.75	18.32	23.917	30.769

chlorophyll-a = 6.28 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, July 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
1	0.00	0.00	-0.77	16.17	-4.246	0.486
2	0.00	0.00	-0.84	16.19	-4.627	0.105
3	0.00	0.00	-0.86	16.21	-4.732	0.000
4	0.00	0.00	-0.80	16.22	-4.397	0.335
51	31.25	0.11	-0.03	15.79	-0.169	4.563
50	39.25	0.14	0.17	15.76	0.962	5.694
48	42.02	0.15	0.29	15.72	1.645	6.377
44	47.38	0.17	0.28	15.71	1.590	6.322
52	81.83	0.29	0.79	15.82	4.452	9.184
53	91.04	0.33	0.80	15.86	4.499	9.231
55	93.53	0.34	0.89	15.91	4.989	9.721
54	95.74	0.34	0.86	15.87	4.831	9.563
57	155.78	0.56	1.28	15.92	7.168	11.900
58	170.63	0.61	1.41	15.96	7.880	12.612
68	171.90	0.62	1.42	16.02	7.903	12.635
59	173.45	0.62	1.43	15.99	7.975	12.707
69	320.10	1.15	1.83	16.06	10.163	14.895
70	334.80	1.21	1.82	16.09	10.087	14.819
71	361.40	1.30	1.81	16.12	10.011	14.743
72	380.30	1.37	1.82	16.14	10.056	14.788

chlorophyll-a = 11.21 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, July 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.69	16.02	-3.774	0.106
37	0.00	0.00	-0.71	16.03	-3.880	0.000
38	0.00	0.00	-0.71	16.12	-3.860	0.020
39	0.00	0.00	-0.65	16.08	-3.541	0.339
17	34.66	0.12	0.47	15.42	2.671	6.551
18	41.12	0.15	0.72	15.45	4.083	7.963
21	45.15	0.16	0.78	15.52	4.404	8.284
19	46.85	0.17	0.79	15.48	4.470	8.350
26	77.60	0.28	1.82	15.67	10.178	14.058
24	80.28	0.29	1.84	15.63	10.312	14.192
22	93.34	0.34	1.99	15.57	11.200	15.080
23	94.00	0.34	1.87	15.62	10.491	14.371
31	144.69	0.52	2.66	15.82	14.734	18.614
30	164.14	0.59	2.83	15.78	15.709	19.589
28	176.59	0.64	2.78	15.73	15.481	19.361
27	180.31	0.65	2.79	15.72	15.553	19.433
36	332.50	1.20	3.39	15.95	18.621	22.501
34	350.40	1.26	3.38	15.92	18.605	22.485
33	373.70	1.35	3.34	15.88	18.423	22.303
32	387.40	1.39	3.47	15.85	19.181	23.061

chlorophyll-a = 11.41 $mg.m^{-3}$

Primary Productivity Raw Data
Station 3, August 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.950	18.82	-2.508	0.000
37	0.00	0.00	-0.930	18.95	-2.438	0.070
38	0.00	0.00	-0.850	18.92	-2.232	0.276
39	0.00	0.00	-0.910	18.85	-2.398	0.110
17	31.95	0.12	0.640	17.77	1.790	4.298
18	42.08	0.15	0.950	17.84	2.647	5.155
19	43.27	0.16	1.200	17.89	3.334	5.842
21	45.94	0.17	1.270	17.92	3.522	6.030
26	61.49	0.22	1.740	18.09	4.781	7.289
24	77.70	0.28	2.290	18.05	6.303	8.811
23	85.87	0.31	2.660	18.02	7.335	9.843
22	94.28	0.34	2.820	17.99	7.791	10.299
30	143.75	0.52	3.710	18.44	9.999	12.507
29	159.16	0.57	3.900	18.35	10.559	13.067
28	163.77	0.59	3.980	18.27	10.825	13.333
27	173.31	0.62	3.990	18.14	10.932	13.440
34	330.90	1.19	4.640	18.77	12.284	14.792
33	333.20	1.20	4.640	18.72	12.317	14.825
31	364.30	1.31	-1.610	18.54	-4.316	-1.808
32	366.60	1.32	4.690	18.62	12.516	15.024

chlorophyll-a = 20.12 $mg.m^{-3}$

Primary Productivity Raw Data
Station 9, August 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
63	0.00	0.00	-1.10	19.44	-2.856	0.075
64	0.00	0.00	-1.13	19.46	-2.931	0.000
65	0.00	0.00	-1.13	19.49	-2.926	0.005
66	0.00	0.00	-1.13	19.51	-2.923	0.008
40	32.37	0.12	0.43	18.79	1.155	4.086
39	40.72	0.15	0.83	18.78	2.231	5.162
38	42.35	0.15	1.14	18.74	3.070	6.001
36	46.66	0.17	1.29	18.73	3.477	6.408
44	94.10	0.34	2.80	19.01	7.434	10.365
43	101.14	0.36	2.88	18.98	7.660	10.591
42	111.53	0.40	3.24	18.91	8.648	11.579
41	122.85	0.44	3.24	18.86	8.671	11.602
45	160.81	0.58	3.67	19.06	9.719	12.650
50	165.88	0.60	3.92	19.19	10.309	13.240
49	175.89	0.63	3.96	19.16	10.432	13.363
48	187.54	0.68	3.96	19.11	10.459	13.390
51	317.00	1.14	4.36	19.21	11.456	14.387
52	334.40	1.20	4.24	19.26	11.112	14.043
53	351.10	1.26	4.32	19.31	11.292	14.223
54	375.10	1.35	4.41	19.43	11.458	14.389

chlorophyll-a = 19.81 $mg.m^{-3}$

Primary Productivity Raw Data
Station 17, August 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
63	0.00	0.00	-0.650	19.03	-2.120	0.000
64	0.00	0.00	-0.650	19.06	-2.117	0.003
65	0.00	0.00	-0.610	19.10	-1.983	0.137
66	0.00	0.00	-0.640	19.13	-2.077	0.043
41	30.44	0.11	0.480	18.53	1.608	3.728
40	39.51	0.14	0.700	18.50	2.349	4.469
38	45.64	0.16	0.870	18.41	2.933	5.053
39	45.82	0.16	0.820	18.46	2.757	4.877
45	95.93	0.35	1.990	18.68	6.613	8.733
44	100.91	0.36	2.050	18.65	6.825	8.945
43	115.99	0.42	2.290	18.61	7.637	9.757
42	123.88	0.45	2.340	18.58	7.818	9.938
48	165.51	0.60	2.550	18.73	8.452	10.572
51	181.25	0.65	2.730	18.83	9.000	11.120
49	184.72	0.66	2.810	18.76	9.297	11.417
50	187.50	0.68	2.750	18.80	9.082	11.202
52	316.80	1.14	3.070	18.88	10.094	12.214
53	360.10	1.30	3.150	18.91	10.339	12.459
54	367.50	1.32	3.190	18.96	10.443	12.563
55	372.80	1.34	3.230	19.00	10.555	12.675

chlorophyll-a = 16.11 $mg.m^{-3}$

Primary Productivity Raw Data
Station 22, August 2000

Bottle #	Light ($\mu E.m^{-2}.s^{-1}$)	Light ($E.m^{-2}.h^{-1}$)	O_2 change ($mg.L^{-1}$)	Time Elapsed (h)	Net photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)	Gross photosynthesis (mg O_2.mg $Chl^{-1}.h^{-1}$)
36	0.00	0.00	-0.630	19.25	-2.357	0.110
37	0.00	0.00	-0.660	19.27	-2.467	0.000
38	0.00	0.00	-0.630	19.30	-2.351	0.116
39	0.00	0.00	-0.580	19.40	-2.153	0.314
17	32.13	0.12	0.480	18.57	1.862	4.329
18	37.27	0.13	0.690	18.60	2.672	5.139
19	41.24	0.15	0.790	18.63	3.054	5.521
21	43.60	0.16	0.810	18.67	3.125	5.592
26	59.53	0.21	1.250	18.87	4.772	7.239
24	70.06	0.25	1.600	18.83	6.119	8.586
23	86.53	0.31	1.830	18.77	7.023	9.490
22	92.92	0.33	1.870	18.73	7.190	9.657
31	146.81	0.53	2.530	19.03	9.574	12.041
30	166.45	0.60	2.690	18.98	10.206	12.673
29	168.14	0.61	2.750	18.93	10.461	12.928
28	181.06	0.65	2.800	18.90	10.670	13.137
36	309.50	1.11	3.240	19.22	12.144	14.611
34	324.30	1.17	3.310	19.17	12.438	14.905
33	361.40	1.30	3.320	19.12	12.509	14.976
32	384.40	1.38	3.340	19.08	12.606	15.073

chlorophyll-a = 13.88 $mg.m^{-3}$

APPENDIX B

VALUES FOR SELECTED FACTORS INFLUENCING PHYTOPLANKTON PRODUCTIVITY

Selected factors influencing phytoplankton productivity (Stations 3 and 9).

Date	Station	$alpha^B$ (mg O_2.mg $Chl^{-1}.E^{-1}.m^2$)	Chl-a (mg. m^{-3})	Extinction (m^{-1})	Turbidity (NTU)	Secchi depth (m)	P^Bmax (mg O_2.mg $Chl^{-1}.hr^{-1}$)	Zeu (m)	Temperature (ºC)	Respiration (mg O_2.mg $Chl^{-1}.hr^{-1}$)	Ik ($\mu E.m^{-2}.s^{-1}$)
Aug-99	3	20.06	36.79	0.92	6.51	0.75	9.07	5.01	32.00	-2.37	125
Oct-99	3	37.50	23.35	1.61	10.18	0.53	10.98	2.86	*	-0.96	81
Nov-99	3	25.87	18.58	0.90	4.47	1.22	6.62	5.12	19.36	-2.39	71
Jan-00	3	37.05	24.07	1.05	6.04	0.82	7.83	4.39	10.20	-1.21	58
Mar-00	3	49.76	10.61	1.57	12.20	0.65	11.63	2.93	15.10	-2.53	64
Apr-00	3	48.97	11.08	1.12	8.64	0.85	21.14	4.11	16.70	-2.08	119
May-00	3	75.45	9.70	1.22	9.90	0.75	41.13	3.77	22.30	-2.50	151
May-00	3	51.49	11.48	0.96	6.22	0.95	15.02	4.80	24.80	-3.47	81
Jun-00	3	56.48	9.57	1.10	5.32	0.85	22.58	4.19	26.50	-1.72	111
Jun-00	3	48.68	15.04	0.85	3.99	0.93	20.17	5.42	26.20	-2.42	115
Jul-00	3	45.65	11.04	0.77	3.31	1.25	21.34	5.98	30.58	-3.49	129
Aug-00	3	36.80	20.12	0.93	1.29	0.85	14.87	4.95	30.00	-2.39	112
Aug-99	9	24.43	27.91	0.75	4.33	1.15	9.19	6.14	32.00	-1.98	104
Oct-99	9	29.40	17.02	1.14	6.12	0.88	11.02	4.04	*	-1.16	104
Nov-99	9	32.93	15.17	0.79	3.68	1.50	7.45	5.83	18.40	-0.90	62
Jan-00	9	37.07	6.34	0.73	4.40	1.48	6.58	6.31	10.40	-1.49	49
Mar-00	9	63.63	3.49	0.74	5.29	0.75	17.64	6.22	13.80	-6.87	77
Apr-00	9	69.97	9.08	0.93	5.78	1.25	21.93	4.95	17.10	-3.46	87
May-00	9	71.70	4.41	0.5	3.90	1.55	46.39	9.21	21.00	-3.51	179
May-00	9	79.20	4.50	0.53	3.17	1.85	30.17	8.69	23.50	-7.48	105
Jun-00	9	58.36	9.03	0.65	2.24	1.55	18.79	7.08	25.80	-1.92	89
Jun-00	9	43.36	15.04	0.72	1.29	1.25	13.42	6.40	25.40	-2.50	120
Jul-00	9	75.44	6.28	0.64	3.27	1.25	30.29	7.20	29.87	-6.33	111
Aug-00	9	38.47	19.81	0.77	4.30	0.95	14.23	5.98	29.40	-2.91	102

Selected factors influencing phytoplankton productivity (Stations 17 and 22).

Date	Station	$alpha^B$ (mg O_2.mg $Chl^{-1}.E^{-1}.m^2$)	Chl-a (mg. m^{-3})	Extinction (m^{-1})	Turbidity (NTU)	Secchi Depth (m)	P^Bmax (mg O_2.mg $Chl^{-1}.hr^{-1}$)	Zeu (m)	Temperature (ºC)	Respiration (mg O_2.mg $Chl^{-1}.hr^{-1}$)	Ik ($\mu E.m^{-2}.s^{-1}$)
Aug-99	17	24.27	22.63	0.69	2.84	1.32	7.77	6.67	29.90	-1.22	88
Oct-99	17	33.15	17.73	1.12	5.56	1.18	8.60	4.11	*	-1.14	72
Nov-99	17	24.57	22.64	0.73	3.02	1.37	7.65	6.31	19.20	-1.66	86
Jan-00	17	37.24	5.27	0.47	2.48	2.20	8.42	9.80	10.30	-1.39	62
Mar-00	17	73.38	2.21	0.46	3.11	2.25	18.58	10.01	12.60	-3.40	70
Apr-00	17	53.16	4.85	0.48	3.42	2.55	24.67	9.59	16.50	-1.61	128
May-00	17	98.96	3.16	0.55	2.22	2.55	45.17	8.37	19.50	-5.42	126
May-00	17	62.74	2.72	0.44	1.65	2.45	33.32	10.47	22.40	-5.27	147
Jun-00	17	79.24	6.81	0.56	2.24	1.85	24.35	8.22	25.80	-6.08	85
Jun-00	17	63.59	3.96	0.32	1.29	3.25	27.49	14.39	24.80	-4.48	120
Jul-00	17	35.99	11.21	0.59	2.54	1.25	14.44	7.81	28.56	-4.50	111
Aug-00	17	31.37	16.11	0.65	2.53	1.05	12.29	7.08	29.50	-2.07	108
Aug-99	22	21.63	18.19	0.72	3.43	1.10	7.29	6.40	31.12	-1.61	93
Oct-99	22	31.58	18.8	1.24	8.25	0.70	9.08	3.71	21.00	-1.26	79
Nov-99	22	20.75	18.3	0.84	4.06	1.20	4.86	5.48	19.30	-0.69	65
Jan-00	22	37.06	8.54	0.70	3.97	1.00	8.18	6.58	10.90	0.18	61
Mar-00	22	41.26	6.98	0.74	5.39	1.15	14.41	6.22	14.30	-1.96	97
Apr-00	22	54.17	4.72	0.87	6.27	1.15	21.95	5.29	16.90	-4.68	112
May-00	22	54.98	2.31	1.39	13.93	0.55	36.59	3.31	21.40	-8.11	1845
May-00	22	43.02	8.32	0.83	4.78	1.25	17.40	5.55	24.40	-3.09	112
Jun-00	22	51.54	15.22	1.09	7.77	0.85	21.17	4.22	25.20	-1.65	114
Jun-00	22	43.83	12.95	0.76	8.23	1.15	16.35	6.06	25.70	-2.18	103
Jul-00	22	53.49	11.41	0.74	4.23	0.85	22.32	6.22	30.97	-3.76	115
Aug-00	22	36.33	13.88	0.73	4.18	0.85	14.67	6.31	29.60	-2.33	112

*Data unavailable

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